ECONOMIC ASPECTS OF POPULATION GROWTH AND WATER CONSUMPTION IN LIBYA

FATHIA F. LAWGALI

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ABSTRACT

Large increases in water demand with very little recharge have strained Libya's groundwater resources, resulting in serious declines in water levels and quality, especially along the Mediterranean coast where most of the agricultural, domestic and industrial activities are concentrated. To meet these increases, Libya turned to desalination as a supplementary water resource as early as 1964. Both thermal and membrane desalination technologies have been used. This study shows that the problem of water scarcity is likely to increase further in the future.

This study has three aims: first, to estimate the historical relationship between population growth and the various uses of water; second, to forecast water consumption according to the various uses; third, to estimate the elasticities of water demand and examine the effect of price, income, population and temperature on water demand in Libya in the short and long-run.

To achieve these aims, an econometric model of Libyan water demand is constructed and estimated for the period 1975-2005, using the Box–Jenkins approach to forecast water demand and the Engle–Granger two-step approach to estimate the short and long-run elasticities of water demand. As a result this study provides considerable information for policy makers concerning current and future Libyan water demand.

By examining the relationships between population growth and the future consumption of water in Libya, it is possible to reach the following conclusions.

- Population growth in Libya will be very high
- Population elasticities for water demand are elastic for agricultural, domestic and industrial purposes. Water demand for all purposes is extremely elastic.
- Most of the population and agricultural lands are concentrated in the northern part of the country.
- The Libyan economy depends heavily on underground water.
- In Libya, as a whole, water demand will increase. Available water in 2020 will be less than half of water demands, implying an increase in the water scarcity problem over time.
- The short and long-run price elasticties are negative, suggesting that there is an inverse relationship between water demands and price. Also, these elasticities indicate that water use is generally inelastic with respect to price.
- The income elasticities are all positive in the short and long-run. This result accords with demand theory , implying that water is a normal good
- The estimation results suggest that, in the long-run, water demand for agricultural, domestic and industrial use is highly elastic for population and inelastic for price and income.
- The short-run elasticities are less than the long-run elasticities, as economic theory suggests. Also, all elasticities in the short-run are less than one. This implies that water demand is inelastic in the short-run.

DEDICATION

In the name of Allah, most gracious and merciful

This thesis is dedicated to my husband **Ahamed** and my daughter **Lamia** for patience, support, love and encouragement.

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DECLARATION

I hereby declare that I am the author of this thesis; that the work of which this thesis is a record has been done by my self, and that it has not previously been accepted for a higher degree.

Signe[redacted]....... Date..May 14th 2009..................

CERTIFICATE

I certify that Fathia F. Lawgali has worked the equivalent of nine terms on this research and the condition of ordinance 36 and related regulation have been fulfilled.

Signed..[redacted] Date........May 13th 2009....................

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CHAPTER ONE

INTRODUCTION

"When you can measure what you are speaking about and express it in numbers, you know something about it...(otherwise) your knowledge is a meagre and unsatisfactory kind ; it may be the beginning of knowledge but you have scarcely in thought advanced to the stage of science[Lord Kelvin 1842-1907]"(Heim and Compton,1992,P.43).

1.0 INTRODUCTION

One of the serious problems that many countries are facing today is water shortage, even though there is over 70% of surface water covering the earth.

Water has been identified as one of the most important natural resources and somewhat different from other resources, because it is viewed as a key to prosperity and wealth. As Marshall (1879) noted, water has played a crucial role in the location, function, and growth of communities.

Lately, global climate change and its impact on rainfall availability and variability in time and space is becoming a concern. Natural factors as well as human actions and inactions are directly responsible for water scarcity problems. Population growth directly or indirectly is expected to shift about 55% of the world's population towards water stress or severe water scarcity over the next generation (Rockström, 2001).

Conflicts over water have always involved competition among alternative uses or among geographical regions, and water is a source of increased controversy, as supplies fail to meet demand. This calls for the careful analysis of decisions pertaining to the allocation of water resources.

So, the aims of this study are to forecast the water demand for agriculture, domestic and industry use in Libya using linear regression methodology. In addition it is focused on total water demand estimation, with especial attention to variable elasticities, model specification, data, and the most common econometric problems. Finally, it is concerned with the relationship between population growth and water consumption in the future.

This chapter consists of six sections. Definitions of water shortages will be in section 1.1. Section 1.2 introduces the background of the research problem while section 1.3 discusses the aims and objectives of the research. Sections 1.4 and 1.5 present the data set, data sources and computer programs used. Finally, the organization of the thesis is described in section 1.6.

1.1 DEFINITION OF WATER SHORTAGES

Water is viewed as a natural resource that has to be managed and sustainably used. Hence, the unsustainable consumption of water may have long-term impacts by reducing available water to communities concerned. Human factors also influence water availability in that available water would have to be harnessed and distributed to ensure adequate and reliable flow.

Other closely interrelated concepts include water scarcity, water shortage, and water stress.

Causes of water scarcity are either natural or induced by the actions and/or inactions of man, resulting in permanent or temporary effects (Falkenmark, 1999; Pereira *et al.*, 2002). Several degrees of water scarcity identified include absolute, life-threatening, seasonal, temporary and cyclical water scarcity (Pereira *et al.*, 2002). Countries with total water withdrawals greater than 50% of the available water resources are said to experience absolute water scarcity (Secklar *et al.,* 1999; lanka Rainwater Harvesting Forum [LRHF], 1999) whilst economic water scarcity prevails if projected water demand is less than 50% of its available water resources but more than twice the current withdrawal levels (LRHF, 1999). Winpenny (1994) attributes high growth in population and food demand as major causes of water scarcity, alongside human behaviour, social customs, institutions and government policies as influencing factors. Growth in urbanization especially in developing countries, industrialization and irrigation are partly responsible for water demand increases at the domestic, commercial and industrial levels. The contamination of existing water supplies, modifying landscapes and land uses, financial and institutional obstacles, and the failure to manage demand have also been mentioned.

There is no widely acceptable definition of water scarcity such that the term water shortage has been used synonymously with water scarcity. When water scarcity is man-induced but with temporary water imbalance including groundwater and surface water over-exploitation, degraded water quality and often associated with disturbed land use and altered carrying capacity of the ecosystems, it is referred to as water shortage (Pereira *et al.*, 2002).

Winpenny (1994) considers water scarcity as an imbalance between supply and demand under prevailing institutional arrangements and/or prices; an excess of demand over available supply; a high rate of utilization (expressed as a percentage of total available water resources) compared to available supply especially when the remaining supply potential is difficult or costly to tap. Though water scarcity describes water demand vis-à-vis its availability in time and space, interpretation of "scarcity" as a situation where water is insufficient to meet normal requirements may be unhelpful to policy makers and planners.

To further conceptualize the problem, Kulshreshtha (1993) suggested a comparison of water withdrawals alongside annual availability to give different scenarios of water scarcity situations. Pereira *et al.* (2002) thus defined water scarcity as a situation where water availability in a country or region is below 1000m3 per capita per year whilst an amount below 500m3 per capita per year is regarded as severe water scarcity.

The water scarcity situation is severe in developing countries, with an estimate of about 1.2 billion people in 20 "water-scarce" developing countries without access to "safe water" (WHO, 1998). By the year 2020, up to 30 countries mainly in Africa and Asia would be in this group. The World Commission for Water (2000) estimates that more than 1 billion people in developing countries do not have access to clean water whilst 2 billion lack adequate sanitation. In the case of sub-Saharan Africa, Rosen and Vincent (1999) estimate that about 67% of the rural population (about 250 million people) lack a safe and accessible water supply whilst 81% do not have access to sanitation facilities. Estimates show that available water per capita has declined by 40% in Asia and 50% in Africa (Ayibotele, 1992).

Africa is noted to be the poorest of the world continents in terms of annual fresh water renewal (World Resources Institute, 1986 as cited by Falkenmark, 1990).

Thus, most sub-Saharan African countries facing economic water scarcity are expected to more than double the amount of developed water supplies by the year 2025 if they are to overcome water insecurity.

Water is a natural resource, renewable in limited quantities through a complex hydrological cycle involving rainfall, surface runoff, rivers, lakes, and ground water. Water is vital for human life and an important component of economic and social development.

Water shortage describes a situation of absolute shortage where low levels of water supply do not meet the necessary minimum requirements for basic needs (Pereira et al., 2002). The inability to sustainably manage water shortage may result in desertification, a permanent situation that is difficult to deal with (Pereira et al., 2002).

There has been a change of approach to water management, which traditionally focused on the supply side .The character of water as a scarce resource and the need to efficiently price its consumption have gained increasing recognition.

Like other economic resources, water shortage is no different from one country and part of a country into another. In the last few years, domestic water shortage has increased worldwide. This can be attributed to the following:

- Increase in the population. Population growth usually increases demand for water in all sectors of the economy: agricultural, domestic and industrial. As Rockstrom, (2001) remarked, "Population growth directly or indirectly is expected to shift about 55% of the World's population towards water stress or severe water scarcity over the next generation".

- Increase in the individual agricultural, domestic and industrial demand. As a result of increasing industrialization, continuing urbanization and rising living standards.
- The geographical and time distribution of water quality and resources do not match the demand. Water is required in some areas and at certain times in greater quantities where it is scarce. In addition, in many regions, water demand exceeds available supplies. So, the impact of global climate change on rainfall availability and variability in time and space cannot be overemphasised.

Rapidly increasing populations in many parts of the world place growing demands on water for agricultural, domestic and industry use. Responses to these increased demands include not only steps such as well drilling, and dam construction, but also improved management of available fresh water. So, the continue increase of population will increase human needs for water.

These reasons have contributed to the shortage of water and as a result the costs of production and preparation for use have risen and the consumer directly or indirectly pays for these costs.

Libya, like other countries worldwide, is no different in respect of the causes leading to the increase of water shortage and I believe that population growth and water consumption are among the areas that should be addressed by any scientific study.

The northern coastal part of Libya (the Libyan coast) presents one of the most vital and fragile ecosystems. As urbanization and other forms of development expanded, 90% of the total population is found within the coastal territories, demand for fresh water escalated so the ground water resources were gradually exploited, extraction exceeded replenishment, water levels subsided and aquifers were subject to seawater intrusion. Facing this situation, the government planned and initiated implementation of ambitious water–transfer scheme through the Great Man–Made River. This area contains most of the farmlands yielding most of the crops, which depend mostly on permanent irrigation, and requires more supplies of water. Therefore, the Great Man-Made River Project was carried out to transport fresh water from underground reservoirs in south Libya to more fertile and cultivable land where most people live, through a network of pipes that are buried at a depth of 7 metres under the ground. The pipe is 1.600 km long and its inner diameter is 4 metres. After the termination of all its networks the pipes will be approximately 4,000 km long, which make it the largest artificial irrigation network in the world.

Water shortages in coastal territories have been growing in magnitude and in frequency of occurrence and may threaten these territories economic development, especially the agricultural sector is facing an increasing scarcity of water. Agriculture relies heavily on irrigation, and despite declining water supplies, it faces the task of expanding food production in order to meet the requirements of an increasing population.

The growth of water demand has a marked impact on the water resources of Libya which suffered serious depletions and quality deterioration (Abufayed and ELghuel, 2001: 48). The common benchmark for water scarcity is 1000 cubic metres/year/person. In Middle East and North Africa, 53 % of the people are said to live with less than 100 cubic metres /year/person (Jacqueline, 2000). Water availability in Libya is very low and does not amount to 1000 cubic metres

/year/person. Renewable resources per person were 538 and 154 cubic metres /year/person in 1960 and 1990, respectively (FAO 2002).

As mentioned earlier, Libya is facing an increasing water demand, while the groundwater, which is the main source of water, is limited and overexploited.

The increasing demand for water in this region, and the declining per capita availability of water in Libya are important factors in the design and implementation of a development strategy for the region. This strategy would have to take into consideration the social and economic implication of declining water resources, and how to maximize the benefits of water under conditions of increasing scarcity.

According to the reports published by the Water Resources Institute, nine countries in the world are considered to be in water crisis. Libya is one of these countries (World Resources 1995).

It is noted that in Libya the amount of water withdrawal is over eight times its renewable water resources. The gap is filled largely by the pumping of fossil groundwater (FAO, 2001). In brief, the water needs of Libya are growing rapidly.

However, to overcome the increasing deficit we must search for non-conventional sources. For example water transfer schemes (The Great Man-Made River Project) water desalination of brackish and sea water seems to offer a sound alternative to arid lands bordering seas of salt lakes; desalination plants producing up to several million gallons per day are commercially available and already used for domestic and industrial purposes in some arid regions and wastewater conservation through recycling and reuse.

1.2 THE PROBLEM OF THE STUDY

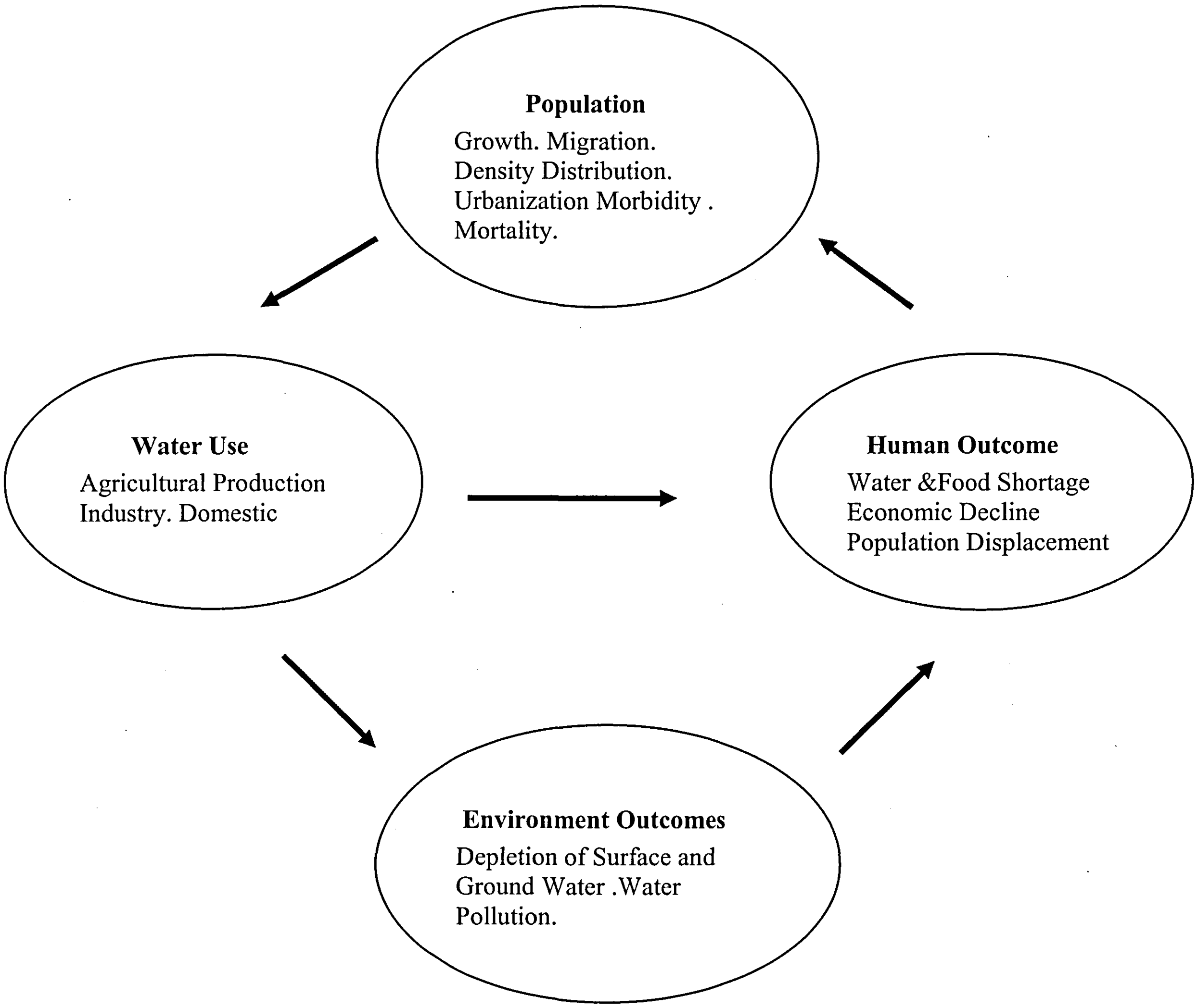
Economic resources are divided into two main types: natural resources and human resources. Water resources fall under natural resources and population falls under human resources, as we know there is a relationship between population growth and demand for water (direct or indirect). Direct demand is the demand for water for drinking and other human needs. The relationship here is direct between population growth and demand on water resources. Indirect demand is the demand for water for agriculture and industry. The relationship here is indirect between population growth and demand on water resources.

During the last three decades the rate of population growth and demographic distribution have been influenced by a variety of social, political and economic factors. Moreover migration from rural areas to cities, especially Tripoli and Benghazi, has resulted in fundamental demographic changes. Average annual growth of the nation's population is around 3.5% in 2005. It is considered one of the highest rates in the world.

Generally speaking population growth is related to a number of factors, the most important of which is the birth rate, death rate and immigration rate. These factors lead to greater increase in population. The increasing population pressure combined with urbanization and economic development will increase water demand, leading to an increased claim on water for various uses. This, in turn, will affect the water reserve.

As referred to earlier, there is a positive relationship between population growth and demand for water for various populations. Although, the main source of water in Libya is groundwater, the reserve of which is affected by continuous consumption especially in the north region, which has the highest population and agricultural land.

Figure (1.1): Population Growth and Water Consumption



As can be seen from figure (1.1) above, there is a relationship between population (growth, distribution, migration, density, urbanization and morbidity) and water consumption which in fact has lead to increased consumption of water for agriculture, industry and domestic purposes and ultimately has lead to economic, social and environment crises.

To summarise, these are the main issues of the study problem.

- The population growth in Libya is very high. It is considered one of the highest rates in the world.
- The Libyan economy depends heavily on under-ground water.
- The agricultural sector is the principal consumer of water in Libya. Furthermore most of the population and the agricultural land are concentrated in the northern parts of the country. There is not enough water for them. In addition, the available data suggest that there is a remarkable shortage of water. That could be explained by the high growth of population and the increase of water demand, directly or indirectly.

1.3 AIMS AND OBJECTIVES OF THE STUDY

The aims of the study are as follows:

- To investigate the present relationship between population growth and various uses of water consumption in the current time period.
- To forecast the relationship between population growth and water consumption according to the various uses. Within these aims, trends of population growth and their determinants as well as the various water resources in Libya will also be dealt with.

- To determine the total water demand in the future.

To achieve these aims the following objectives were set for the study:

- The Box-Jenkins approach is used to estimate and forecast the model.
- The Engle-Granger two step approach is used to examine the elasticity for all variables in the lung and short run. Also to show the reaction of demand when one of the variables changes.

In order to realize the goals of the study, the subject of population growth and its relation with water consumption is placed in a group of statements in order to be discussed, while handling all aspects of the subject matter.

These facts are as follows:

- There is a large population growth due to the increase of fertility, decrease of mortality and increase of the immigration rate.
- The water supplies (water sources) are considered to be relatively limited in Libya, when compared to some neighbouring countries.
- Whenever the population increases, the more water is consumed directly or indirectly. Therefore, this affect the water reservoirs by decreasing them.
- Mostly, the state is the responsible authority for water supply for the different purposes.
- This study will be at the aggregate level .That is because the data are limited and not available to the extent needed for disaggregate purposes.
- This study handles the subject from an economic point of view.

1.4 DATA SET AND DATA SOURCES

1.4.1 Data Set

In most developing countries, including Libya, data and information needed for research are limited and sometimes unavailable. The problems in these countries include short time series of data, lack of monthly and quarterly data. Missing observations and variables and the imposition of secrecy on some data and information. Compared with developed countries, data in developing countries also has less reliability. This is due to technical inexperience. In addition to the above problems, some unpublished data can usually only be obtained through a personal contact.

In the Libyan economy, the process of compiling national accounts takes some time and final estimators are not usually ready for publishing until about two or three years after the end of the year under consideration. This is due to the lack of quarterly statistical data.

This study is based on annual time series data over 1975 to 2005. In addition, all monetary data used to estimate the model are valued in the Libyan currency (i.e. Libyan Dinar)[1]

In theory, the estimation of population water demand functions within a micro setting using population data is the preferred approach (Scherter and David, 1985; Young, 1996; Saleth and Dinar, 2000). However, attempts at the micro level are rather few, since they require a great volume of information. This fact and the characteristics of several variables included in the demand function (especially personal income) make it difficult to obtain a good sample of micro

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[1] Libyan Dinar approximately = £1.0000 in 1966 and = £2.3280 in 2005

data. Studies estimating micro-level water demand are, among others: Hanke and De Mare (1982), Jones and Morris (1984), Nieswadomy and Molina (1989), Schneider and Whitlatch(1991), Hewitt and Hanemann (1995), Maresca et al.(1997), and Arbues et al.(2000).

1.4.2 Data Sources

This study requires collecting and analysing data for the period 1975 to 2005. This data is annual data is because only annual data is available covering this period and information related to the relationship between population growth and water demand in Libya. In order to identify the indicators that explain such a relationship the study relies extensively on water use data for the period 1975 to 2005 compiled every year by the Ministry of General Planning, General Water Authority and the General Investment of the Great Man-Made River. However, historical population data has taken from Great Socialist People's Libyan Arab Jamahiriya and Jamahiriya statistical year book for the years from 1975 to 2005. Historical data and projections for income were obtained from the Central Bank of Libya and total population is used as the determinant of domestic, industry and as agriculture water use.

For studying and analysing the research problem, it relied on the data and information issued by the Public Corporation of Water, the General People's Committee of Planning, the General People's Committee of Agriculture and the General Corporation for Investment of the Great Man-Made River Waters. All reference data were collected from Libyan Authorities: Libyan Meteorological Department; General Environmental Authority; General Water Resources the Public Corporation of Water, the General People's Committee of Planning, the

General People's Committee of Agriculture and the General Corporation for Investment of the Great Man-Made River Waters.

1.5 COMPUTER PROGRAMS USED

Illustrations and data analyses contained in this study were achieved using different programs: SPSS 11, Excel 2003, and EViews4, (computer software) available in Dundee Business School. The full text of the thesis is typed using the word processing (Word 2003) system.

1.6 ORGANISATION OF THE THESIS

This study is organised into ten chapters followed by the main results and recommendations as follows:

In the first chapter the problem of the study is defined and the goal of it as well as the sources of data and information is specified. Chapter two reviews the literature relevant to this topic, theoretically as well as empirically and econometric models. This chapter discusses the econometrics background and review of references.

The main objective of chapter two is to overview the field of study without focusing on a specific area within the investigated phenomenon. Chapter three provides a general background to the Libyan environment. The fourth chapter focuses on the population growth and the factors determining it through reviewing the aspects of population growth, its factors and the density of population. While the water supply, Man-Made River and water demand are defined in chapters five and six.

Chapter seven focuses on the analysis of the future water demand by using Box Jenkins modelling. The Engle-Granger two-step procedure is introduced in chapter eight to determine variable elasticities for water demand for all purposes. Chapter nine is an overview of the relationship between population growth and water consumption in future. Chapter ten is the summary, conclusions and recommendations, which give an overview of the study, the main findings of this study, limitations of study and suggestions for future research.

CHAPTER TWO

MODELLING OF WATER DEMAND AND WATER RESOURCES A REVIEW OF THE LITERATURE

2.0 INTRODUCTION

The purpose of this chapter is to review the experience of researchers in the area of modeling water demands and water resources. A thorough understanding of the factors that give rise to the use of water resources is a critical requirement for effective planning and management of water resources.

Modelling of water demand consists of the search for variables that underlie or determine water demand and the determination of their relationships to water use in quantitative terms.

The results of previous studies contain important information about the principal explanatory variables and their mathematical relationship to water demand. Because researchers have defined water demand in many different ways, many models appear in the literature.

In this chapter, special emphasis is placed on the models of aggregate and disaggregate demands, which consider total demands of a group of water users who use water for a similar set of purposes, or total demands of various often dissimilar users within a defined geographical area. Although this chapter does not present a comprehensive review of the literature of water demand modelling and water resources, a sufficient number of citations is included to provide a representative sample of the approaches that have been employed to explore water demand.

A review of the literature was carried out in order to identify studies of water demand and water resources. The initial compilation of relevant references was obtained by searching the Internet with the use of appropriate keywords. Also, the search of references available through the system of libraries.

This chapter is divided into seven sections. Section 2.1 introduces a literature review of theory. The econometric background is discussed in section 2.2. Estimation of water use is provided in section 2.3. Section 2.4 outlines the water use relationships. Methodology is discussed in section 2.5. Section 2.6 introduces the review of references and discusses the results of more than sixteen studies on the subject. Finally, a general summary of the whole chapter is presented in section 2.7.

2.1 REVIEW OF THEORY

2.1.1 Definition

The most general definition of water use relates to the hydrologic cycle, which describes and quantifies the movement of water in the world's hydrosphere. The atmospheric precipitation that falls on land represents the global stock of annually renewable freshwater. The latter represents surface and subsurface runoff, which turns into streams, lakes and rivers (Falkenmark, 2000).

The most restrictive definition of water use refers to water that is actually used for a specific purpose. For example, the USGS water use circulars distinguish ten categories of off-stream use including (Solley, et al., 1998):

Domestic use: Water for household needs such as drinking, food preparation, bathing, washing clothes and dishes, flushing toilets, and watering lawns and gardens (often referred to as residential water use).

Irrigation use: Artificial application of water on lands to assist in the growing of crops and pastures or to maintain vegetative growth in recreational lands such as parks and golf courses.

Industrial use: Water for industrial purposes, including fabrication, processing, washing, and cooling.

Economists define the demand for water as the relationship between water use and price, when all other factors are held constant. Demand is a negative functional relationship represented by the demand curve. This curve describes the relationship between price and water use for a single user. The demand imposed by each water user can be represented by a similar demand curve, and all such curves are expected to be negatively sloped (increased price results in decreased water use).

When a number of users face a price which is uniform over the group, their individual demand curves can be summed horizontally to obtain an aggregate demand curve. The aggregated demand curve, usually called a market demand curve, is also negatively sloped. The shape and position of the demand curve are determined by the values of other explanatory variables, such as income, price and so on.

The effect of increasing income is to shift the curve to the right, so that the same price would result in progressively larger quantities of water being used. The effect of increasing price is a movement along the curve to the left.

Water supply planning rarely requires that the entire demand curve be known. More often, it is sufficient to know how specified incremental changes in explanatory variables will affect water use. In the case of price, this information is contained in the slope of the demand curve. The slope gives the incremental change in water use for an incremental change in price, at some position on the curve. Because of the units chosen for axes of the demand curve, the slope of the curve has an inconvenient dimension. It is customary, therefore, to use a dimensionless measure of the relationship, calculated by dividing the fractional (instead of incremental) change in water use by the fractional change in price. This dimensionless measure is known as the elasticity, here called the price elasticity of water demand. It is defined for an arc of the curve as:

$$\eta = \frac{Q_2 - Q_1}{Q^*} \div \frac{P_2 - P_1}{P^*}$$

Where:

Q_1 = First quantity

Q_2 = Second quantity

P_1 = First price

P_2 = Second price

$Q^* = (Q_1 + Q_2)/2 \quad and \quad P^* = (P_1 + P_2)/2$

A more frequently used definition is based on the derivative of the demand function, and yields the elasticity at a specific point on the curve as follows:

$$\eta = \frac{dQ}{dP}\frac{P}{Q}$$

Where water use is a function of price and other variables, the ordinary derivative is replaced with a partial derivative:

$$\eta = \frac{\partial Q}{\partial P}\frac{P}{Q}$$

Both definitions give an elasticity, which is expected to be a negative quantity (because the demand curve is negatively sloped). Price elasticity may be interpreted as the percentage change in quantity which would result from a one percent change in price. A price elasticity of -0.5, therefore, indicates that a 1.0 percent *increase* in price would be expected to result in a 0.5 percent decrease in quantity demanded.

2.1.2 Linear Function[1]

The simplest form of water use function uses no transformation at all; it is simply a multivariate linear relationship:

$$y = \alpha + b_1 x_1 + b_2 x_2 + u \qquad (2\text{-}1)$$

Where:

α, b_1, b_2 are parameters

x_1, x_2 are explanatory variables such as income, population

[1] For more details for all equations in sections 2.1.2, 2.1.3, 2.1.4, and 2.15 see Solely 1998 and Gujarati 2003.

y is the dependent variable such as water

u is the error term

When income and other explanatory variables are held constant, (2-1) is reduced to the following expression:

$$y = \overline{\alpha} + b_1 x_1 \qquad (2\text{-}2)$$

Where $\overline{\alpha} = \alpha + b_2 \overline{x}_2$ and $E(u) = 0$

The elasticity for x_1 is calculated as follows:

$$\eta = b_1 \frac{x_1}{y} \qquad (2\text{-}3)$$

In most cases, the elasticity is calculated at the means $(\overline{y}, \overline{x})$

2.1.3 Log-Linear Model

A log-linear demand function is similar to a linear function, except that the dependent variable (y) is replaced with its log transform (Usually, its natural logarithm). This yields the following form:

$$In(y) = \alpha + b_1 x_1 + b_2 x_2 + u \qquad (2\text{-}4)$$

Taking the antilog of both sides would give:

$$y = e^{(\alpha + b_1 x_1 + b_2 x_2 + u)} \qquad (2\text{-}5)$$

Holding all factors except x constant yields the following expression:

$$y = \overline{\alpha} * e^{b_1 x_1} \qquad (2\text{-}6)$$

Where $\overline{\alpha} = e\alpha + b_2 x_2$ and $E(u) = 0$

The elasticity for x can be calculated as:

$$\eta = b_1 x_1 \qquad (2\text{-}7)$$

2.1.4 Log-Partial Log Model

A further variant of the log-linear form includes log transform for the dependent and some, but not all, of the right-hand-side variables. An example of this form is:

$$\ln(y) = \alpha + b_1 x_1 + b_2 \ln(x_2) + u \qquad (2\text{-}8)$$

The alternative form is:

$$y = e^{(\alpha + b_1 x_1 + u)} * b_2 x_2 \qquad (2\text{-}9)$$

The demand curve, holding x_2 constant, would have the following form:

$$y = \overline{\alpha} * e^{\alpha + b_1 x_1} \qquad (2\text{-}10)$$

Where $\overline{\alpha} = x_1$ and $\mathrm{E}(u) = 0$

As in the case of the log-linear model, the elasticity for x is directly proportional to x:

$$\eta = b_1 x_1 \qquad (2\text{-}11)$$

2.1.5 Double-Log Model

The final variant of this class of demand function is a multivariate linear model with all variables replaced with their log transforms. The model has the following form:

$$\ln(y) = \alpha + b_1 \ln(x_1) + b_2 \ln(x_2) + u \qquad (2\text{-}12)$$

The function can also be written as:

$$y = e^{(\alpha+u)} * x_1^{\;b_1} * x_2^{\;b_2} \qquad (2\text{-}13)$$

The two-parameter demand curve (with other variables held constant) is:

$$y = \overline{\alpha} \;\; * x_1^{\;b_1} \qquad (2\text{-}14)$$

Where $\overline{\alpha} = e^{\alpha} x_2^{\;b_2}$ and $\mathrm{E}(u) = 0$

The price elasticity of demand of the double-log model is constant, which is:

$\eta = b_1$

2.2 THE ECONOMETRIC BACKGROUND

Past studies of water demand were mostly based on cross-country data; only a few studies used time series data from individual countries. It is generally believed that single country time series analysis is more useful, as it can capture country-specific features that may not be found in a cross-country analysis. Note though that time series data may produce spurious relations if the variables under study are linked to common factors. If the variables follow a time trend (that is, their means and variances are not constant over time), they are said to be nonstationary. Two nonstationary variables may be found related, while in fact they are not, simply because of the common nature of their time trends. According to Engle and Granger (1987), the direct application of ordinary least squares or generalized least squares to nonstationary data produces regression results that are misspecified or spurious in nature. These regressions tend to produce performance statistics that are inflated, such as high R^2, F and t-statistic, which often lead researchers to commit Type I errors (Granger and Newbld, 1974)[2].

It is, therefore, important to test the nature of the time series data. Most macroeconomic time series data are found to be nonstationary or integrated of order 1, denoted by I(1). That is, they can be made stationary by differencing the series once.[3] Earlier researchers who performed single-country analysis used first differences of the time series data to avoid spurious regression. However, this creates the problem of losing long-run information on the variables.

To deal with this, researchers are increasingly using cointegration and the error correction mechanism (ECM) to estimate time series relationships. In general a linear combination of I(1) series is integrated of order 1 . However, there exists a special case where the linear combination of I(1) can be I(0) or stationary. In that case, the series are said to be cointegrated.

It must be remembered that the effect of economic growth in any one year is likely to be lagged and longer term. Cointegration allows us to test for the presence of a non-spurious long-run equilibrium relationship between the variables under study in a multivariate setting with and without a time trend. Both contegration and the error correction mechanism investigate long-run linkages and short-run dynamics among the variables.

The aim of this section is to construct a small macro-econometric model for Libyan water demand. In order to do this a basic econometric background is needed. Box-Jenkins modelling will be used to forecast the water demand for all

[2] Type I error means the null hypothesis is rejected when it should not have been.

[3] If a time series has to be differenced d times, it is integrated of order d or I (d). If d=0, the resulting I (0) process represents a stationary time series.

purposes and the Engle-Granger approach will be used to estimate water demand for all purposes to investigate the long-run relationship as well as the short-run relationships using the Error Correction Model (ECM) to determine variable elasticities for water demand for all purposes. Also this section will present the basic background for the concepts of stationarity, the cointegration approach, and error correction models respectively.

2.2.1 Box-Jenkins Modelling

The Box-Jenkins approach to modelling ARIMA processes was described in a highly influential book by statisticians George Box and Gwilym Jenkins in 1970. An ARIMA process is a mathematical model used for forecasting. Box-Jenkins modelling involves identifying an appropriate ARIMA process, fitting it to the data, and then using the fitted model for forecasting. One of the attractive features of the Box-Jenkins approach to forecasting is that ARIMA processes are a very rich class of possible models and it is usually possible to find a process which provides an adequate description to the data. The original Box-Jenkins modelling procedure involved an iterative three-stage process of identification, estimation and diagnostic testing.

2.2.1.1 Stationary and Non-Stationary Time Series

In addition to the choice of estimation techniques for an econometric model, it is necessary to consider whether the time series variables are stationary or non-stationary. The reason stationarity is important is because it is one of the basic assumptions made in modelling and forecasting (Holden and Thompson;

1992:76). The non-stationarity of variables often leads to a problem of spurious regression. Stationarity is defined as the tendency of a variable to return to its mean value and fluctuate around it, while a non-stationarity series has a different mean at different points (Holden and Thompson, 1992, Moosa, 1992-1993, and Harris, 1995). Suppose, that a variable Y_t is generated by a first-order auto-regressive process.

$$Y_t = \alpha + \rho Y_{t-1} + u_t \tag{2-15}$$

In the above equation the variable Y_t will be stationary if $|\rho| < 1$. If $|\rho| \geq 1$

Y_t will be nonstationary. The variable Y_t depends on last period's Y_{t-1} and an error term.

The variable Y_t is covariance stationary if:

- E(Y_t) $= u$, constant for all t
- Var(Y_t) =E$(Y_t - u_t)^2 = \sigma^2$, constant for all t
- $\operatorname{cov}(Y_t - Y_{t+n}) = E(Y_t - u_t)(Y_{t=n} - u_t) = \gamma_n$ constant for all t (Thompson, 1993 and Harris, 1995).

Thus, it is possible to conclude that a stochastic process is stationary if the mean, variance, and covariance of a series remain constant over time (Holden, Thompson, 1993, Harris, 1995 and Thomas, 1993). The non-stationary series can be transformed to be stationary by taking their first or second differences. For example, if Y_t is non-stationary the first difference $\Delta Y_t = Y_t - Y_{t-1}$ or second difference $\Delta^2 Y_t = Y_t - 2Y_{t-1} + Y_{t-2}$ is stationary.

A stationary series is said to be integrated of order zero, $I(0)$. If Y_t is non-stationary but its first difference is stationary Y_t is integrated of order one, $I(1)$. In summary the series is integrated of order d, $I(d)$, if it needs to be differenced (d) times to become stationary. The number of times a variable needs to be differenced in order to induce stationarity depends on the number of unit roots it contains (Harris, 1995:18).

2.2.1.2 Testing for Stationarity

Since the stationarity of data series is important in regression analysis, this should be tested before estimating the model. In this context, testing for unit roots (stationarity) has received a great deal of attention in the literature in the last decade.

In the literature, several methods of testing for the presence of unit roots (stationarity) in time series data have been introduced. These methods consider the null hypothesis that a series contains a unit root (it is non-stationary). Sargan and Bhargava (1983) introduced the Co-integrating Regression Durbin-Watson statistic (CRDW) based on the usual Durbin-Watson statistic (DW) to test the null hypothesis that a variable is stationary or a group of variables are not cointegrated. Phillips and Perron (1988) developed non-parametric (Z) tests based on Phillips' (1987) paper which transforms the test statistic to eliminate any auto-correlation in the model. Dickey and Fuller (DF) (1979, 1981) provide test statistics similar to the standard t tests but with different critical values. The most popular one is probably the basic DF and ADF tests because of their simplicity or their more general nature (Harris, 1995:28). Thus the next sub-section is addressed to explaining the Dickey-Fuller methodology of testing for unit roots.

2.2.1.3 Dickey-Fuller Tests

Dickey-Fuller Tests can be carried out by considering three regression specifications.

$$Y_t = \alpha_1 Y_{t-1} + u_t \tag{2-16}$$

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + u_t \tag{2-17}$$

$$Y_t = \alpha_0 + \alpha_1 Y_{t-1} + \gamma t + u_t \tag{2-18}$$

The three regressions differ according to whether the mean of the series is zero [as in (2-16)] or the mean is non-zero [as in (2-17)] or the mean is non–zero and time trend, t, is included [as in (2-18)]. The tests involve estimating whether the value of α_1 is equal to one, or less than one. If $|\alpha_1|$ is one (or greater than 1) the Y_t series is not stationary, if $|\alpha_1|$ is less than one the Y_t the series is stationary (Holden and Thompson, 1992; 12-13).

Considering a series described by equation (2-17) Y_t, is to be stationary only if -1< α_1<+1. If it is not, Dickey and Fuller (1981) suggested some transformations to remove the complication of non-stationarity. Now, (2-17) can be re-written as

$$Y_t - Y_{t-1} = (\alpha_1 - 1)Y_{t-1} + u_t \tag{2-19}$$

Suppose $(\alpha_1 - 1) = \beta$, equation (2-19) can be re-parameterised as follows

$$\Delta Y_t = \beta Y_{t-1} + u_t \quad , \qquad \beta = (\alpha_1 - 1) \qquad (2\text{-}20)$$

In the case of the above equation, two general tests are defined: the Dickey-Fuller test and the Augmented Dickey-Fuller (ADF) test[4]. The DF test involves estimating the above equation and testing if β is zero. It is only valid if the residuals from the above equation are free from auto-correlation. If auto-correlation is present, the introduction of lags of the first difference of the series on the right hand side of the above equation is required to remove it. This gives the ADF test. In both tests the significance of the 't' statistic on the Y_{t-1} variable is checked by comparing it with the appropriate value in special tables provided by Fuller (1976) and Dickey and Fuller (1981). In a similar way (2-17) and (2-18) can be re-parameterised to

$$\Delta Y_t = \alpha_0 + \beta Y_{t-1} + u_t \qquad (2\text{-}21)$$

$$\Delta Y_t = \alpha_0 + \beta Y_{t-1} + \gamma t + u_t \qquad (2\text{-}22)$$

Thus, three specifications of DF and ADF tests are defined as τ, τ_u and τ_t in which the τ statistic is relevant for the regression with no intercept and time trend, τ_u with just the intercept, and τ_u with both intercept and time trend (Dickey and Fuller, 1981).

[4]The tests cover the case of I(1) and I(0) variables. While I(2) and I(3) variables sometimes occur, the most common cases are I(1) and I(0)

2.2.2 Engle-Granger Two-Step Procedure

The Engle-Granger two-step procedure is used to test for the existence of cointegration. The first step is to estimate the long-run static model of order one and the second step in this procedure is to estimate the error correction model (ECM) to give the short-run dynamic relationship. Section 2.2.2.3 will carry out elasticity estimates for all variables in the long and short-run. To achieve these goals applications of stationarity tests will be used to check the stationarity and the order of integration of each individual variable in section.

2.2.2 .1 The Cointegration Concept

The importance of stationariy has been well recognised for many years. Wold's (1938) theorem states that a stationary time series process with no deterministic components has an infinite moving average (MA) representation. In general this can be represented by a finite auto-regressive moving average (ARIMA) process. (Box and Jenkins, 1970, Hannan, 1970). However, as mentioned in the last section, some economic time series need to be differenced in order to achieve stationarity. Hence, Engle and Granger (1987) introduced a definition of integration: a series with no deterministic component which has a stationary, invertible ARIMA representation after differencing d times, is said to be integrated of order d, denoted $x \Rightarrow I(d)$. (Engle and Granger; 1987:253).

Thus, a time series integrated of order $I(0)$ is stationary in its level while a time series integrated of order one $I(1)$ is stationary in its first differences. Examples of time series integrated of order zero $I(0)$ are a white noise series, and a stable first order auto-regressive [AR(1)] process. A random walk process is an example of a time series integrated of order one $I(1)$. (Dolado et al, 1990). The differences between series integrated of order zero $I(0)$ and order one $I(1)$ have been recognised and discussed by Engle and Granger (1987). They pointed out that an $I(0)$ series (i) has finite variance which does not depend on time, (ii) has only a limited memory of its past behaviour (i.e. the effects of a particular random innovation are only transitory), (iii) tends to fluctuate around the mean (which may include a deterministic trend), and (iv) has autocorrelations that decline rapidly as the lag increases. For the case of an $I(1)$ series, the main features are (i) the variance depends upon time and goes to infinity as time goes to infinity, (ii) the process has an infinitely long memory (i.e. an innovation will permanently affect the process), (iii) it wanders widely, and (iv) the autocorrelations tend to one in magnitude for all time separations. (Dolado et al; 1990:251). Now consider two time series y_t and x_t both $I(d)$. It is normally true that any linear combination of the two variables will also be $I(d)$. More generally, the addition or subtraction of two series integrated to different orders will result in a third series which is integrated to the same order as the more highly integrated of the two original series. This is because the variable of the higher order series will dominate that of the lower order series. (Holden and Thompson; 1992:7). If, however, there exists a vector β, such that the combination

$$u_t = y_t - \beta x_t \qquad (2\text{-}23)$$

is of a lower order of integration $I(d-b)$, where $b > 0$, Engle and Granger (1987) define y_t and x_t as cointegrated of order (d,b) and $CI(d,b)$. The most common cases are $d = 1$ and $b = 1$ but other cases might arise. Here β is the cointegration vector. The above discussion can be summarised in Engle and Granger's (1987) own words:

Consider $z_t = \alpha' x_t$

The components of the vector x_t are said to be cointegrated of order d,b denoted $x_t \approx CI(d,b)$, if (i) all component of x_t are $I(d)$;(ii) there exists a vector $\alpha \neq 0$ (0 is vector) so that $z_t = \alpha' x_t \approx I(d-b), b > 0$. The vector α is called the cointegrating vector (Engle and Granger; 1987:253). Consequently, the co integration concept specifies the existence of a long-run equilibrium to which an economic system converges over time. Thus, u_t in equation (2-23) can be interpreted as the equilibrium error (Dolado et al, 1990, and Holden &Thompson, 1992).

2.2.2.2 Testing for Cointegration

Several statistical tests have been developed to test for cointegration in time series. Dickey and Fuller (1981), Sargan and Bhargava (1983) Engle and Granger (1987), Stock and Watson (1988), and Johansen (1988) have suggested alternative tests and methods for testing and estimating the cointegration vectors. Surveys of this literature include Dolado el al, 1990, Holden and Thompson, 1992 and Muscatelli and Hurn, 1992.

Given two $I(1)$ series, y_t, x_t one test for cointegration is to estimate (2-23) in the form $y_t = \alpha + \beta x_t + u_t$

by ordinary least squares and test if u_t is $I(0)$ by means of the Dickey-Fuller test. This involves estimating

$$\Delta u_t = \alpha_0 + \beta_0 u_{t-1} + \varepsilon_t$$

Where ε is white noise the second test for stastionarity is on the size of β_0. If there is cointegration then Engle and Granger (1987) suggest a two-step method, which determines u_t as above in the first step. The second step is to test u_t for stastionarity since they are the residuals of the cointegration regression. If the residuals are stationary, the variables in the cointegration regression are cointegrated.

The Engle and Granger (1987) two step method is valid only if the cointegration vector is unique, which will be the case with two variables when economic theory suggests y depends on x. However, real world economic relationships are complicated, and theoretical relationships frequently include more than two variables. Thus, the property of uniqueness may be lost, and more than one cointegration vector is possible. Johansen (1988) proposed a method to identify the maximum number of cointegration vectors in a multivariate framework. As mentioned the Johansen (1988) method will be used to investigate whether any stable long-run relationships exist between exogenous and endogenous variables of the model.

2.2.2.3 Estimation of Error Correction Models

Estimating the long run of the cointegration relationships is the first step for estimating the complete model. The short-run structure of the model is also needed. Engle and Granger (1987) present a theorem (it is called the Granger representation theorem) that, if two variables are integrated of order one $I(1)$ and are co integrated $CI(1,1)$, then an error correction model (ECM) exists. For ease of exposition one can assume that the cointegration regression has the following form

$$Y_t = B_0 + B_1 X_t + B_2 X_{2t} + \ldots.. + B_n X_{nt} + u_t \qquad (2\text{-}24)$$

The estimated value of the dependent variable Y is given by

$$Y_t = b_0 + b_1 X_t + b_2 X_{2t} + \ldots.. + b_n X_{nt} + Z_t \qquad (2\text{-}25)$$

In this case the ECM is given as follows

$$\Delta Y_t = \theta_0 + \theta_1 Z_{t-1} + \Sigma \theta_2 \Delta Y_{t-j} + \ldots.. + \Sigma \theta_3 \Delta Y_{t-j} + \varepsilon_t \qquad (2\text{-}26)$$

$$Z_t = Y -_t b_0 + b_1 X_t + b_2 X_{2t} + \ldots.. + b_n X_{nt} \qquad (2\text{-}27)$$

Where Δ denotes the first difference (i.e. $Y_t - Y_{t-1}$), Z is the residual form, θ_t are parameters, and ε is a vector of random variables with mean zero and variance σ^2. The ECM shows that changes in Y_t depend not only on changes in X_t but, also on the extent of disequilibrium between the levels of Y and X as measured by Z_t. If Y_t is above its equilibrium value in (2-25) for the given values of $X_1, X_2., ...X_n$ then from (2-27) Z_t will be positive, and since in (2-26) θ_1 is expected to be negative, the net effect of the Z_t term in (2-26) will be to reduce ΔY_t so that Y_t moves back towards the equilibrium value. That is, the 'error' at time t-1 is partially 'corrected' at time t, with the extent of the correction being determined by the sizes of θ_1 and Z.

2.3 ESTIMATION OF WATER USE

The reported quantities of water use can be in the form of direct measurements obtained from water meters which register the volume of flow (such as displacement meters or Venturi tubes) or they may be estimated. Estimates of water use that are derived from the measurements of water levels or from pumping logs are generally more accurate than those derived from related data on the volume of water-using activity. For example, the estimates of water use for hydroelectric power generation may be obtained by multiplying the amount of generated power by a water use coefficient.

The measurements of water use are reported as water volume per unit of time. The volumetric units include cubic metres, cubic feet, gallons and litres, and their decimal multiples. In some cases, composite volumetric units such as acre-foot or units of water depth such as inches of rain may be used. The time periods used include a second, minute, day, and year. Because the annual volumes of water usually involve large numbers, the water use numeric data are often reported as the average daily quantities used. Two popular units are thousand cubic metres per day (Km3/d) and million gallons per day (mgd).

In order to make the estimates of water use easy to comprehend and to make meaningful comparisons of water use for various purposes (and various users), the annual or daily quantities are divided by some measures of size for each purpose of use. The result is an average rate of water use such as gallons per capita per day (gcd), gallons per employee per day (ged), or other unit-use coefficients.

2.4 WATER USE RELATIONSHIPS

In general, water use relationships are in the form of mathematical equations which express water use as a mathematical function of one or more independent variables. The mathematical form (i.e., linear, multiplicative, exponential) and the selection of the right hand side (RHS) or independent (explanatory) variables depend on the type and aggregation of water demand represented by the left-hand side (LHS) or dependent variable.

Depending on the purpose for which water use estimations or forecasts are used, different representations of the dependent variable may be used. For example, in hydrologic studies of surface and groundwater resources, water use is usually represented as daily, monthly or yearly withdrawals at a point such as a river intake or a well.

Because the water withdrawn is typically used (or applied) over a larger land area, an equivalent hydrologic definition of water use would be the use of water within a defined geographical area (e.g. an urban area, a township, a county, or a river basin or sub-basin) which is derived from a single point of withdrawal.

2.5 METHODOLOGY

The relevant literature together with the research objectives provided the basis for the appropriate methodological approach which determines the data collection and the methods of analysis. Methodology focuses on how to gain knowledge about the world and is about a way to investigate phenomena (Lincoln and Guba, 1985; Guba, 1990).

This section discusses the methodology and research method adopted to conduct this research project in order to achieve the research objectives. This section is divided into three parts. The first part presents the theoretical framework and specification of the model. In the second part, the specification of the water demand model is discussed. The third part focuses on the forecasting model.

2.5.1 Theoretical Framework and Specification of the Model

Consumer demand theory is the underlying framework to model total water demand. The understanding of total optimization problems depend on issues regarding total preferences or choices which lead to the existence of utility functions, commodity separability and aggregation, and resulting in the consumer demand equations adopted in modeling consumer demand systems. The choice of approach matters because models that do not conform to fundamental consumer behaviour may lead to misspecification and wrong policy prescriptions. There is usually a dilemma between realism and theory. This study makes forecasts of future water demand until 2025 based on major determinants (population, income, price, temperature, agriculture use, domestic use, and industry use,) and information from 1975 to 2005 about trends in water use. In the study, the water use coefficients for the three water use categories are estimated, future water uses in each category are projected, based on estimated water use coefficients and the projected value of water use determinants.

2.5.2 Specification of the Water Demand Model

2.5.2.1 Introduction to the Model

Past studies of water demand were mostly based on cross-country data; only a few study time series data from individual countries. It is generally believed that single country time series analysis is more useful, as it can capture country-specific features that may not be found in a cross-country analysis. Time series data may produce spurious relations if the variables are linked to common factors. If the variables follow a time trend (that is, their means and variances are not constant over time), they are said to be nonstationary. Two nonstationary variables may be found related, while in fact they are not, simply because of the common nature of their time trend. Thus, according to Engle and Granger (1987), the direct application of ordinary least squares or generalized least squares to nonstationary data produces regression results that are misspecified or spurious in nature. These regressions tend to produce performance statistics that are inflated, such as high R^2, F and t-statistic, which often lead researchers to commit type I errors (Granger and Newbold, 1974).[5]

The use of price to manage water demand has been an issue of growing concern among decision-makers during the last decade. Economists have tried to shed some light on the effects of different types of water estimating demand functions and normally focusing on the calculation of price. To this end, some type of econometric model is derived of the form $Y = (p, y, pop, temp)$ which relates water consumption to some measure of price (p) and other factors such as income, temperature and population. However, there is no general consensus on the methodology to analyse water demand.

Since the 1960s (Gottlieb, 1963; Howe and Linaweaver, 1967), water demand has been extensively studied, with the focus on either aggregate municipal demand or residential demand (See OECD, 1987; Baumam et al., 1997, p. 67, for compilations of early studies). The estimated values of the price of water demand vary widely. Espey et al (1997) used meta-analysis[6] to show differences in estimated price due to the inclusion or not of explanatory variables other than price in the demand function, the choice of function form of estimation technique, and type of data.

[5] Type I error means the null hypothesis is rejected when it should not have been.

[6] A meta-analysis consists of a set of statistical procedures designed to accumulate experimental and correlation results across independent studies. Meta-analysts translate results from different studies to a common measure and statistically explore the relation between study characteristics and findings

However, the meta-analysis obscures important qualitative information. Using study findings as the units of analysis produces non-independent data and gives greater weight to studies with many comparisons. Averaging across constructs and including studies with obvious methodological flaws can confuse the reliability of findings. Also, the study by Espey et al. (1997) is not recent enough to include many interesting developments in water demand estimation.

This section discusses the relative merits of the statistical procedures for estimating total water demand. First, the main variables that determine water demand will be discussed, with particular attention to price selection.

Differences in the data sets and different models of demand specification employed will then be evaluated. Finally, some estimation problems and suggested solutions will be presented

Variables

Population served, income, price of water, and weather conditions constitute the major determinants of water use. Because each of these general variables can be specified in different ways, the alternative specification of the same variable are interrelated and therefore are not likely to be included in any single model of water use. Other variables may have only marginal contribution to the explanation of variation in water use.

The economic approach to water demand estimation uses econometric techniques to relate water consumption to some measure of the water demand and a set of explanatory variables such as income price, temperature and population. A selection of these independent variables is described next.

Water Price

Water demand in most cases is estimated as rather inelastic with respect to price. This is because water has no substitutes for basic uses and because the customer exhibits a low level of perception of the rate structure, since water bills typically represent a small proportion of income (Chicoine and Ramamurthy, 1986; Arbuer et. 2000). However, prices can play a crucial role in demand management as long as the elasticities are different from zero.

2.5.2.2 Other Variables

Income

Income is generally considered to be an important determinant of water use. Two widely used income variables are median family income and per capita income. According to economic theory, the expectation is that water use will increase with increasing income. Income elasticity is a measure of how changes in income will influence water demand. For example, an income elasticity of 0.5 suggests that a 1.0 percent increase in income will result in a 0.5 percent increase in the quantity of water demanded (or used).

In studies that use aggregate data, the income measure is normally total money income for the area divided by population. This variable could be introduced in addition to income, acting as a proxy for wealth and population preferences for life style. However, it is normally too correlated with income and other variables to be useful in practice (Lyman, 1992; Barkatullah, 1996).

Population

If the dependent variable is water use in agriculture, domestic, and industry, population should positively affect use. However, due to economies of scale in the use of water, the increase in water use is less than proportional to the increase in population (Hoglund, 1999). However, as Arbues et al. (2000) show, there is an optimum population beyond which these economies of scale vanish.

Temperature

Temperature in water demand is very important and should be included in every equation (agricultural, industrial and domestic) in this model.

2.5.3 The Forecasting Model

2.5.3.1 Water Demand Equations

$$W = W_A + W_D + W_I \qquad (2\text{-}28)$$

Where W = total water demand, W_A, W_D, W_I = water demand for the purposes of agriculture, domestic and industry use, respectively

$$W_A = f(P_A, Y, pop, temp) \qquad (2\text{-}29)$$

$$\frac{W_A}{pop} = f\left(P_A, \frac{Y}{pop}, temp\right) \qquad (2\text{-}30)$$

Where P_A is the price of agricultural water, Y is income, pop is the number of people and $temp$ is the temperature

$$W_D = f(P_D, Y, pop, temp) \qquad (2\text{-}31)$$

$$\frac{W_D}{pop} = f\left(P_D, \frac{Y}{pop}, temp\right) \qquad (2\text{-}32)$$

Where P_D is the price of domestic water.

$$W_I = f(P_I, Y, pop, temp) \tag{2-33}$$

$$\frac{W_I}{pop} = f\left(P_I, \frac{Y}{pop}, temp\right) \tag{2-34}$$

Where P_I is the price of industry water.

Substituting equations (2-29), (2-31) and (2-33) into equation (2-35)

$$W = W_A + W_D + W_I \tag{2-35}$$

$$\begin{aligned} W = {} & W_A(P_A, Y, pop\ , temp) + W_D(P_D, Y, pop, temp) + \\ & W_I(P_I, Y, pop, temp) \end{aligned} \tag{2-36}$$

$$W = f(P_A, P_D, P_I, Y, pop, temp) \tag{2-37}$$

$$\frac{W}{pop} = f\left(P_A, P_D, P_I, \frac{Y}{pop}, temp\right) \tag{2-38}$$

The estimation model is:

$$\ln W_A = \alpha_A + \beta_1 \ln P_A + \theta_1 \ln pop + \gamma_1 \ln Y + \psi_1 \ln temp + u_A \tag{2-39}$$

$$\ln W_D = \alpha_D + \beta_2 \ln P_D + \theta_2 \ln pop + \gamma_2 \ln Y + \psi_2 \ln temp + u_D \tag{2-40}$$

$$\ln W_I = \alpha_I + \beta_3 \ln P_I + \theta_3 \ln pop + \gamma_3 \ln Y + \psi_3 \ln temp + u_I \tag{2-41}$$

$$\begin{aligned} \ln W = {} & \alpha + \beta_1 \ln P_A + \beta_2 \ln P_D + \beta_3 \ln P_I + \theta \ln pop + \gamma \ln Y \\ & + \psi \ln temp + u \end{aligned} \tag{2-42}$$

Where:

$\alpha, \alpha_A, \alpha_D, \alpha_I$ = Intercept coefficients

$\beta_1, \beta_2, \beta_3, \theta, \theta_1, \theta_2, \theta_3, \gamma, \gamma_1, \gamma_2, \gamma_3, \psi, \psi_1, \psi_2, \psi_3$ = Slope coefficients

u = Residual term

ln = Natural logarithm

The double logarithmic function form is commonly used in econometrics because its slope coefficients represent constant elasticities and to reduce nonlinearity.

Linear water demand functions are often chosen because of their ease of estimation. These can be derived from a quadratic utility function, but are most often presented with no formal derivation (Al-Quanibet and Johnston, 1985). The linear regression functional form is sometimes criticized, because it implies that the change in quantity demanded in response to a price change is the same at every price level (Billings and Day, 1989).

2.6 REVIEW OF REFERENCES

2.6.1 Water Resources in Libya

Libya enjoys large underground reserves of fresh water in the great sedimentary basins of Al-Kufrah and Sarir. These basins occupy the south eastern part of the country. There is no doubt that ample quantities of groundwater of acceptable quality occur at the sites selected for the Great Man-Made River Project for the estimated 50 year life time of the project and longer (Pallas, 1980). For the last four decades, these basins were subjected to extensive hydro geological studies at the regional and sub regional scale. The following are examples of these studies:

Ball (1927) made the first attempt to construct a groundwater map of this region. He concluded that the Nubian aquifers are continuously recharged by rainfall in the high regions situated to the southwest in the Erdi-Ennedi-Tibisti Mountains where the rainfall ranges from 328 to 920 mm. These conclusions are supported by Ezzat (1959), Sanford (1953), and Gabert (1961).

Sandford (1953) concluded in his study that the aquifers gained a substantial amount of groundwater at present from Wadi Hawa, in Erdi area. He estimated recharge at the rate of 4.6 million cubic meters daily. Hellstrome (1940) and Murray (1952) on the other hand believe that the aquifer is not recharged at the present time. Pallas (1978) attributed the flow to the slow emptying of this huge reservoir filled up by the rainfall of the quaternary pluvial periods.

Dubief (1963) has analyzed the recent meteorological data of the North African stations, and concluded that the rainfall does not seem to have shown any definite variation in North Africa during the past 120 years. Jones (1964) constructed a regional water level map for Libya. He subdivided Libya into 19 groundwater systems based on geological criteria. However, Pallas (1978) reduced these systems to five based upon hydraulic relationships. In 1968, Occidental Oil Company drilled experimental water wells in the Al-kufrah Oasis based on Jones' studies.

According to Jones (1969) the Al-kufrah basin covers an area of 245,000 km2 and available water resources from storage in the groundwater reservoir of the basin is in the order of 25,000 km3 of good quality water. Jones (1964) estimates annual extraction from about 600 wells which were in use at that time was probably less than 2km 3, in addition to the significant natural discharge which is limited to Al- kufrah oasis area. The deepest well drilled in this area was 838 m, which penetrated a friable and poorly consolidated sandstone aquifer.

The Al-kufrah basin is a part of a major groundwater province of south eastern Libya, which extends to Chad, Sudan and Egypt. The groundwater is contained within 3,000 meters of porous sandstones and is of excellent quality (500 mg/kg). (UNESCO/UNDP1972) reported that the annual rainfall at zone southern flank of Tibisti in the six years of observation averaged about 30.5 mm with a maximum rainfall of 131 mm. They reported 100 m annual rainfall at Trouan Natron 2,000 m above the mean sea level based on two years of observations. Assuming an average rainfall of 50 mm over an area of 20.000 km2, the volume of precipitation would be approximately 1,000 million cubic metres per year.

(Unesco/Undp 1972) stated that in the Hugger and Tibiisti mountains, which rise to heights of 2,158 and3, 262 m respectively, rains occur occasionally, but the rainfall rarely exceeds 100 mm. The very occasional storms give rise to considerable surface runoff that sweeps down suddenly from the mountain valleys to soak. As these phenomena occur for a very brief period only and over a limited surface, evaporation losses are relatively light. The major proportion of the water infiltrates directly, and these apparent losses may well be the main source of replenishment of the aquifers in the north of the drainage basins.

Since 1st September 1969, about 50 agricultural projects have been completed throughout Libya. However, two major desert projects, Al-kufrah production project and Sarir production project, have been in operation since 1971 and 1975, respectively. Jalu settlement project (Shaath 1970) and Tazerbo production project (Ahmad 1979) were constructed in south-eastern Libya Sahara.

At the recommendation of James R .Jones, Occidental Oil Company drilled wells in the Al- Kufrah oasis in 1968. In July 1970, the project came under the control of the Ministry of Agriculture. Tipton & Kalmback (1972), a consulting firm, was hired by the Ministry of agriculture, and a well field (KPP) consisting of 102 wells was constructed under their supervision.

In the Al-kufrah settlement project (KSP), a similar field consisting of 35 wells was constructed in 1974 and 1975. Each well is designed to pump 76 litre /second to settle 16 families for farming.

Schoute (1976) calculated low transmissivity values from the pumping test results. The transmissivity and storage values had been modified in various models in order to predict the behaviour of the well field, and they were lower than those estimated from the longer series of observation. Schoute's calculations indicated a drawdown of 4 metres at a distance of 30 kilometres and drawdown of 1 meter at a distance of 40 kilometres after 40 years of pumping.

2.6.2 Water Studies

2.6.2.1 Water Demand[7]

Reviews of the empirical literature on water demand show the dominance of residential (urban) over that of rural water demand studies. Single and system demand equations with different functional forms have been employed to estimate elasticities of water demand with respect to price, income, population characteristics and composition, among others. These studies utilise time series, cross-sectional data or panel data.

[7] Water demand is defined as the quantity of water required or needed by various water users or customers

Arbués *et al.* (2003) notes the absence of a general consensus regarding the methodology to analyse water demand and this has resulted in different ranges in price-elasticity estimates of water demand. Through meta-analyses of residential water demand studies, Espey *et al.* (1997) as cited by Arbués *et al.* (2003) attribute these differences to the functional form estimation technique, type of data used, the choice of variables included (in addition to water price) such as income, temperature variables, household population, housing characteristics, frequency of billings and tariff rate designs, and indoor versus outdoor uses. Using Ordinary Least Squares (OLS) estimation, the price elasticity estimates range from -0.21 to -1.57 (Howe and Linaweaver, 1967), -0.39 to -3.33 (Lyman, 1992) and -0.04 to-1.24 (Pint, 1999). A combination of OLS and water prices gives price elasticity estimates from -0.16 to -0.38 (Griffin and Chang, 1990). Using panel-data techniques with price variables, Nauges and Thomas (2000) estimate price elasticity at -0.22. Hewitt and Hanemann (1995) employed the instrumental variable approach in combination with marginal price and its difference to give price elasticity estimates between -1.57 and -1.63. These results mainly come from developed countries.

In the developing country context, water demand management in general has traditionally focused on supply-side policies (Arbués *et al.*, 2003) that aim at improved water supply coverage for the entire population at low tariffs (Atlaf, 1994). This strategy has been shown to produce low service levels (Briscoe and de Ferrenti, 1998) especially in rural areas and therefore unsustainable in that rural water supply schemes have been approached as welfare activities without financial viability considerations (Saleth, 1996). Willingness to pay (WTP) studies through the contingent valuation approach have been used to investigate the potential value to consumers of an improvement in water supply. Studies show that households are willing to pay between 0.5% and 10% of income for improved water services. Although household income is an important determinant of demand, other factors are found to be more important in the demand for improved water services in rural areas of developing countries (World Bank Water Demand Research Team, 1993). Garn (1998) mentions differences in cost (or price), water quality perceptions, reliability, and level of service between existing and improved supplies in rural areas as significant in affecting demand.

Empirical findings indicate that rural households demand a high level of service (World Bank Water Demand Research Team, 1993), are willing to pay more for improved water supply and services and are already spending substantial amounts to circumvent low services (Whittington *et al.*, 1990; Mangin, 1991; Brookshire and Whittington, 1993; Atlaf, 1994). In Kathmandu, Nepal, Whittington *et al.,*(2002) find that households' willingness to pay for improved water services is much higher than their current water bills, where unconnected households are WTP a monthly average of US$ 11.67 for private connections.

Attention has lately shifted to a demand-oriented approach where the price of water is used as the main instrument to regulate demand. Community-based approaches have been suggested by Parker and Skytta (2000) but without clear distinctions between these approaches. Zekri and Dinar (2003) find price a significant determinant of water demand in rural Tunisia, with a price elasticity of -1.29 (for a private supply arrangement) and -0.24 (for a public supply arrangement). They attribute the observed high absolute price elasticity to high levels of poverty for consumers of private water companies. The study also finds that low water quality (proxied by salinity) significantly reduces water demand whilst household income has no significant effect on quantity demanded. Minten *et al.*, (2002) apply OLS estimation and find household size (elasticity of 0.31) and income (elasticity of 0.11), but not distance, as significant factors that explain household water demand in 8 rural communities in Madagascar. The insignificance of distance is attributed to the closeness of the sources (i.e., lakes and rivers with an average of 12 minutes one-way). However, their study presents a serious drawback by excluding water price, a tool employed in water management to regulate demand.

Using seemingly unrelated regressions, Acharya and Barbier (2002) find that in two areas (four villages) in the Hadejis-Jama'are floodplain in northern Nigeria, time devoted to water collection did not significantly explain water demand by households who only collect water.

However, time significantly determines water demand by households who both collect and purchase water where a 1% increase in collection time decrease the demand for collected water by 3.19% and increases the demand for purchased water by 1.69%. Whilst the price of water does not explain water demand by this group of households (i.e., those who collect and purchase water), price of purchased water is significant in explaining demand for purchased water where a 1% increase results in a 1.667% decrease in its demand for purchased water by both groups of households. Household size significantly explains the demand for collected and purchased water for these two groups of households.

2.6.2.2 Water Consumption[8]

Wide differences exist between water consumption levels in industrialised and developing countries. Average per capita daily water consumption (l/c/d) for Switzerland, the least among industrialised countries, is 110 l/c/d, USA (668 l/c/d) and Japan (342 l/c/d) (World Bank, 1997b as cited by Rosen and Vincent, 1999). In comparison, although at the village level, an average of 11.1 l/c/d is observed for a village in Mozambique with a centrally located standpipe 300 metres away (Caincross and Cliff, 1987 as cited by Rosen and Vincent, 1999). Consumption averaged only 4.1 l/c/d (ibid, 1987) in another village in the same country with a similar water source located 4 km away from home. Acharya and Barbier (2002) report an average of 232 litres per day per household or 24 l/c/d for two wetland communities in northern Nigeria. In Madagascar, a survey of 180 households in 8 villages reveals that on the average households consume 31 litres of water daily in the dry season (Minten *et al.,* 2002). No such documented information exists for rural communities in Libya. What is available is a survey conducted by London Economics (1999) on behalf of the Ministry of Works and Housing (MWH) in major urban areas to justify the introduction of Private Sector Participation (PSP) in the urban water sector. They report an average of 105.1 l/c/d for households with tap connections, 68.5 l/c/d for those with yard tap and 33.2 l/c/d for those using other means, with an average domestic water demand estimated at 52 l/c/d for the urban sector.

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[8] Water consumption commonly refers to the portion of water withdrawals that are not returned to the same source or not able to be reused in the local area.

To further enhance water security, multiple water sources are utilised depending on the season and geographic location. Ariyabandu (2001) report that between 2 and 6 sources of water have been used among the rainwater harvesting community in rural Sri Lanka. The burden of domestic water provision by women and children (usually girls) in developing countries is well known (Curtis, 1986 as cited by Sullivan, 2002; Rosen and Vincent, 1999).

Locating improved water supplies within reasonable distances to households saves time and possibly increases total water consumption. Although the World Health Organisation (WHO) considers 200 metres as a convenient distance, Sharma *et al.*, (1996) as cited by Rosen and Vincent (1999) points out that when rural households' perceptions of accessibility is considered, the percentage of households with safe water supply access could substantially reduce and may approach zero in some cases.

Studies reviewed by Rosen and Vincent (1999) suggest that time saved by women is channelled into housework (for example, cooking and hygiene), rest, social and personal activities. Others allocated time saved to having quality time with the family whilst a few invested this time into agricultural and cottage income generating activities (Ariyabandu, 2001).

2.6.3 Models of Water Demand:

2.6.3.1 Models of Water Demand: a summary

1. Moore, C.V 1963.

Purpose: This study estimates the static-normative demand for irrigation water for individual farms in Tulare County, California, a highly intensive crop farm area, by using a linear programming approach.

Model Specification and Estimation: A parametric-objective function (variable-cost) programming method–a modification of the standard simplex linear programming model was applied for this study. However, details on this model are not included in this paper.

Comments: Two critical assumptions may not be necessarily valid as the authors indicated: (1) that producers have complete knowledge of commodity prices; and (2) that each producer's goal is to maximize farm income. Other limitations include the uncertainties regarding changes in technology and socioeconomic environment and lack of probability statement.

2. Flinn, J.C. 1969.

Purpose: The purpose of this paper was to estimate farm and regional demand schedules for irrigation water and to derive the relationships between the seasonal and intra-seasonal demand schedules for irrigation water. The study derived "synthetic" demand estimates using linear programming.

The study examines the demand for irrigation under different agricultural/farm production orientations and during different seasons.

Model Specification and Estimation: The demand schedules for irrigation water were generated for each of the five representative farm models.

Linear functions $Q = \beta_0 + \beta_1 P$ were fitted to the five farm demand schedules where *q* is the water delivered in acre, *p* is the price in dollars per acre, and *B'S* are coefficients. The horizontal summation of the demand schedules of the individual producers in each region was used to determine the aggregate regional demand schedule. Demand for irrigation water during the spring, summer, and autumn seasons was investigated.

Comments: The author notes that there are limitations to this study related to linear programming approach. In addition, uncertain factors on future prices, technologies, institutional constraints, and subjective factors (such as different attitudes about accepting risk) may affect the results of derived demand curves. Moreover, in agriculture the temperature variable is very important and should be included in every modeling application.

3. Burke, T. R 1970.

Purpose: The purpose of this study was to develop an econometric model of municipal water requirements that reflects various factors affecting demand, and that uses only readily-available published data. The model was developed as part of the Economic Evaluation Model System,

Model Specification and Estimation: A log linear functional form was used to estimate the water demand model for each of the 19 Pseudo states, and sub-state size groupings. A stepwise regression procedure was used to estimate the models.

The log linear model is expressed as:

$$\log Y_i = \log \alpha + \beta_1 \log X_{1i} + \beta_2 \log X_{2i} + K + \beta_K \log X_{Ki} + \varepsilon_i$$

I=1, 2, ...19

Comments: This paper is largely an early "primer" on the statistical estimation of water demand. Two appendices are included discussions of the use of logarithmic transformations in modeling and levels of significance

4. De Rooy, J, 1974.

Purpose: 1- Present a simple model of water demand by manufacturing firms;

2- Provide evidence that industrial users respond to small changes in unit price.

Model Specification and Estimation: The demand for water for cooling, processing and steam power for each firm was represented by the Cobb-Douglas production function

$$g_{wit} = F_T X_t^{\alpha} P_{rjt}^{\beta(r)} P_{wjt}^{\beta(w)} T_t^{y}$$

Where X*t* is output of the *t*th firm, P*rjt* and P*wjt* are the unit cost of recycled water and price of water respectively,. For sanitation purposes, water demand was assumed to be a simple linear function of employment (E*t*) that could be described by:

$$g_{wst} = \varepsilon E_t$$

the weighted mean of Pwjt and Prjt , was introduced:

$$P_{Gjt} = \lfloor P_{wjt} g_{wjt} + P_{rjt}(G_{jt} - g_{wjt}) \rfloor / G_{jt}$$

Where Gjt is defined as gross water use by the tth firm, for the jth use, if no water is recycled.

The revised demand function (3) for water in the industrial sector then becomes:

$$g_{wt} = G_{jt} = F_t X_t^{\alpha} P_{Gjt}^{\beta} T_t^{\alpha}$$

Comments: The authors argue that the results of their study using cross-sectional data are likely to be "more relevant" than those that could be derived from time-series data. This is based upon the observation that plants using large quantities of water are likely to locate in areas where water is plentiful and cheap, and therefore "geographical price differentials are greater than observed variations over time." As expected from economic theory, the author observed that the firms respond to increases in price of water by reducing demand, however, this relationship is nonlinear.

5. Foster, H S. and Bruce R. B. 1979.

Purpose: The purpose of this study was to develop a single-equation econometric model for estimating urban residential water demand that is uniformly applicable to all localities in the United States, and to test the hypothesis that "residential water demand is invariant to city size and among sub regions of the United States."

Model Specification and Estimation: The estimated aggregate model from the cross-sectional data for the 218 cities was

$Q = 0.2492^{-0.1278P} I^{0.4619} R^{-0.1679} H^{0.4245}$

Where: Q= average quantity of water per residential meter (1,000 cubic feet per year); p = average water price (dollars per 1000 cubic feet); I = median household income (dollars per year); R = precipitation during growing season (inches); and H = average number of residents per meter. The estimated model accounted for 54.5 percent of cross-sectional variance in the dependent variable

Comments: The authors provide an extensive discussion of issues related to the estimation of water demand functions and provide a comparison of the results for the price coefficient to those of previous studies. Demand curves were estimated and plotted for each of the six regions that were analyzed, however, non-price variable were held constant at their regional means.

6. Nieswiadomy, M. 1985.

Purpose: This study had three objectives. First, it introduced a new methodology to calculate groundwater pump age. Second, by using the calculated groundwater pump age it estimated a water demand function to test the Gisser-Sanchez rule. Third it conducted a sensitivity analysis to reveal the role of groundwater management in the High Plains of Texas.

Model Specification and Estimation: The demand models included the following variables: expected prices of cotton (P1) and grain sorghum (P2), pumping cost (PC), wage rate (W), the price of furrow irrigation (F), and rainfall. Rainfall was divided into three periods: pre-planting rainfall (Rain 1: October to December of previous year), planting rainfall (Rain 2: January to May), and peak growing season rainfall (Rain 3: June to August). A cross-section ally correlated and time-wise autoregressive model was used. Both linear and log-log functional forms were adopted for estimation.

Comments: The results shows that both linear and log-log models fit the 1973-80 data better than the 1957-72 data. In particular the log-log model has a very high F-statistic and high R2 value. The log-log model showed that the elasticity of water demand is –0.80. Rainfall variables are significant in most models.

7. Griffin, R. C., and Chan, C. 1990.

Purpose: The purpose of this study was to investigate the use of average price versus marginal price in the analysis of community water demand.

Model Specification and Estimation: Using ordinary least square (OLS) method, the demand for residential water in thirty communities was estimated and the resulting model was:

$$Q = 26.84 - 26.78AP - 1.23PQ + 5.36CH + 9.95I + 0.185SP + 0.0731C$$

(2.21) (-11.91) (-0.35) (-1.55) (7.88) (0.70) (23.67)

where Q is the per capita residential and commercial water consumption (gallons per capita per day); AP is the average price of water paid by an average 2.84 person household; MP is the marginal price of water paid by an average 2.84 person household (average and marginal price include both water and sewer rates); PO is the difference between marginal and average price (MP-AP); CH is the rate change dummy variable (1 if a rate change occurred during the current or previous two months, 0 otherwise); I is the annual personal income per capita(Thousands of dollars); SP is percent of the population of Spanish origin; and C is a climate variable (number of days without rainfall -0.25 inches times average monthly temperature in Fahrenheit). The average price and PO were included in order to compare the sensitivity of average price and marginal price to the demand function.

Comments: The authors note that the accurate incorporation of sewer rates into the water price variable can be arduous. The unique climate variable developed for this study was highly significant. The dependent variable used in the model is per capita residential and commercial consumption. The authors state that the results of their analysis suggest that higher summer water rates can be an effective conservation tool.

8. Klimek, J, C. 1992

Purpose: The purpose of this study is to estimate daily water intake in manufacturing in the case of Oswego Basin of New York State. The estimates are disaggregated by source, function and disposition.

Model Specification and Estimation: A model of projected industry withdrawal requirements was developed. The daily manufacturing withdrawal in each period for each county were estimated using the equation:

$F(I) = INT\{A(I)\ B(I)\ D(I)\ W(I)-W(I)\ P(I)W(I)\ P(I)/\ Q(I)$

Where F(I) is daily withdrawal by industry group; A(I) is base period employment; B(I) is employment change, D(I) is change in productivity per employee; W(I) is weighted intake per employee; P(I) is percent of intake subject to reuse; and Q(I) is weighted reuse rate.

Comments: It was concluded that changes in daily intake and water reuse would be moderate. The rate of water needs was estimated to increase at a compound rate of 1.6 percent annually. The results indicated that the greatest gains in manufacturing activity would occur in industries which were not major users. Gross water requirements met by withdrawal were estimated to decline from 70 percent to 59 percent.

9. Dziegielewski, B and Donald W. H. 1994.

Purpose: The purpose of the study is to quantify water use patterns of high-density residential sector of water users in New York City and forecast the sector's water demand. High-density residential sector (HDR) is defined as all housing units in buildings with three or more units.

Model Specification and Estimation:

Where:

$Q_s = 333.2 = 130.3PD - 8.15G - 0165D - 58.8B_2 - 20.3B_4$

$R^2 = 0.40$ R = 120

SEE = 127.0

Q_s = average water use per unit in small buildings (with 3 units) in gallons per day

PD = population density in persons per unit

B2 = binary variable designating Brooklyn

B4 = binary variable designating Queens

G = building age in years

D = number of metered consumption days

10. Dandy, and Davies 1997

Purpose: The analysis here differs from most previous research in that it explicitly recognizes that water consumption free allowance, being sensitive to price. The model specification and estimation procedures used here should be of interest to those interested in the demand for water.

Model Specification and Estimation: The demand for water is assumed to have the following linear form:

$$Q = \alpha_0 + \alpha_1 Q_{-1} + B_1 I + BZ + \theta D_Y + \delta_0 D + \delta_1 DQ_{-1} + \gamma_1 DI + \Gamma DZ + \phi DP + u$$

where

Q = quantity of water consumed

Q_{-1} = quantity of water consumed in previous year

A=annual allowance

D =1 for Q>A and D = 0 for Q$\leq$A;

D_y =1 for year = 1992 and D_y = 0 otherwise

Comments: They note that

1-Regression analysis was used to model residential water demand for the city of Adelaide for a sample of households.

2-The marginal price variable was included to measure the effect of an increase in the price of the next unit of water.

11. Espey, M., J. and Shaw, W.D. 1997.

Purpose: This paper presents a meta-analysis of price elasticity of residential water demand using inter study differences as variables in a regression analysis to explain the variation in the reported elasticities.

Model Specification and Estimation: The authors use a meta-analysis approach to estimate a model that uses price elasticity estimates from previous studies as the dependent variable. Explanatory variables are derived from model characteristics of the reviewed studies. These can be grouped into four categories: demand specification income-population density-household size-lagged dependent- variables estimation technique all other approaches.

Comments: The article includes a discussion of the theory of price elasticity of demand, as well as several tables that provide details of previous research.

The authors present recommendations and cautions for the use of previous price elasticity studies in the development of water resource policies and practices.

12. Abdul, K .S.1998

Purpose: This paper uses annual and quarterly data on consumption of fresh water in Kuwait to forecast the demand for this vital commodity by the year 2000 The aim of this paper is to forecast the demand for water in Kuwait using Box – Jenkins methodology.

Model Specification and Estimation: Demand for water in Kuwait using:

1-The regression model

$\mathrm{Log}_e \mathrm{DW}_t = \alpha_0 + rt + u_t$

DW_t = demand for fresh water in period t

t = time

α and r =constants to be estimated

r = represents the constant growth rate

m = an error term

2- ARIMA (1, 1, 1) model

$\mathrm{Z}_t = \phi_t + \mathrm{Z}_{t-1} - \psi_{1\alpha_{t-1}}$

$\mathrm{Z}_t = \mathrm{X}_t - \mathrm{Y}_{t-1}$

Comments:

1-Fresh water in Kuwait has been growing

2-The demand for fresh water is expected to be highest in the July –September quarter and lowest in the January-March quarter.

3-The point forecasts obtained from annual data differ from the corresponding forecasts using quarterly data, by some10 per cent, due to the difference in data coverage.

13. Hooker, M .A. and Wendy E. A. 1998.

Purpose: The purpose of the study is to estimate the demand for surface irrigation water directly from disaggregated profit functions for fields in the San Joaquin Valley of California. Demand schedules and elasticities are estimated directly from a field-level optimization by using the saline crop-water production functions for three crops: tomatoes, cotton and alfalfa.

Model Specification and Estimation: For each crop, the profit function is defined by:

$$\Pi_{ij} = \max\{P_j * f_j[(a_1 + a_2), i, q, c - w_1 a_1 - w_2 a_2 - V_{ij}(a_1, a_2, f) - k_i - k_j\}$$

where *a1* and *a2* are quantities of surface and ground water in hectare-centimeters, *i* istechnology index, *q* is a measure of water quality, and *c* is weather; *Pj* is the price of the crop *j*; *w1* and *w2* are the prices of surface and ground water; *V ( )* is a crop- and technology- specific function giving costs of production as a function of water inputs and crop output; and *ki* and *kj* are fixed costs related to technology *i* and crop *j*.

Comments: The authors concluded that the demand for water is very inelastic and irrigation used only surface water. As price increases, a mixture of surface and ground water was used, even though the elasticity was still inelastic. After this, price elasticities become elastic and the demand for water changed from surface water to ground water.

14. Masciopinto, C and Marcello B. 1999.

Purpose: The purpose of this paper was to forecast drinking water needs for every municipality within the Po Basin of Northern Italy using factor analysis followed by the multiple regression modeling.

Model Specification and Estimation: The following variables were considered to be included in the statistical analysis: total municipal incomes (*Rc*), total number of apartments (*X1*), total number of stores (*X2*), total water requirement (*Vi*), store employees (*X3*), total patients in hospitals (*X4*), type of municipality (*Tc*), urbanization level (*X5*), industrial activity loads (Ip), municipality location in relevant catchment (*X6*), total guest in hotels (X7), municipality location in relevant sub catchment (Sb).

Factor analysis reduced the variables to five: *Rc*, *VI*, *Tc*, *Ip*, *Sb*, and *P*.

Water consumption in this study was characterized by a two-dimensional analysis. A second factor analysis was carried out to create two indices *F1* and *F2*, which are the anthropogenic activity and the water availability, respectively.

$$F_1 = 0.5\ 1_P + 0.5\ V_i 0.14T_c + 0.12S_b + 0.11R_c + 0.02P \quad (2)$$

$$F_2 = 0.021_P + 0.02\ V_i + 0.5\ T_c + 0.4S_b + 0.01R_c + 0.6P \quad (3)$$

Equation (2) and (3) were then used to make linear statistical models:

$$C_m = a_1 F_1 + a_2 F_2 + c \quad (4)$$

where *a1*, *a2*, and *c* indicate the regression coefficients and the constant.

Comments: Results of the estimated drinking water demand indicated that total volumes are extremely sensitive to variations in the anthropogenic activity. Therefore, the correct evaluation of growth trends for the anthropogenic activities will enable more appropriate estimations of the water volumes to be supplied in the region. The authors claimed that by means of this methodology, the regional water distribution can be envisaged and planned by relevant authorities through actions on the different factor trends

15. Brown, T. C. 2000.

Purpose: The study made forecasts of future water use (year 2040) based on major water use determinants (population, income, electric energy production, and irrigated acreage) and information on 1960-1995 trends in water use efficiency.

Model Specification and Estimation: In the study, the water use coefficients for the five water use categories were estimated based on past trends. Future water use in each category is projected, based on estimated water-use coefficients and projected values of water use determinants.

Comments: In the last part of the article, the author acknowledges that some factors that can affect water use were not analyzed, such as water price, regulations affecting the efficiency of water-using appliances, and so on. In addition, the projections only apply to the average year and large-scale regions, not to the dry years or specific locations that experience above average impacts.

16. Celine, N and Alban .T. 2003

Purpose: They show in this paper that a dynamic model of water consumption can be derived from a structural optimization program solved by local communities. This nonlinear model is estimated on a sample of French municipalities and is found asymptotically equivalent to a dynamic panel data model that is linear in the parameters.

Model Specification and Estimation: Dynamic panel data model:

The model is following:

$$Y_{it} = \delta Y_{i,t-1} + X_{it}^{'} B + u_{it},$$

i =1, ...N; t=1,........,

Comments: They note that the residential water is more elastic in the long run then in the short run. This result can be explained by the slow adaptation of the households' behavior to the variation in prices. Price of water has been very low a long time and consumers could have got into habits of wasting water.

2.6.4 Elasticities of Water Demand:

Table (2.1) Elasticities of Water Price, Income and Temperature: a summary

Study	Variables	Elasticity
Moore et al., 1963	Water Price in Agricultural use	-0.702 -0.188
De Rooy, 1974	Weighted mean of unit cost of recycled water and price of new water	-0.894 -0.745 -0.741
Darr et al., 1975	Monthly income per capita	0.58 0.48
Foster et al., 1979	Median household income	0.46
Berk et al., 1980	Mean monthly temperature	1.37
Berk et al., 1980	Mean monthly temperature	2.74
Griffin et al., 1990	**Annual per capita income** 1.Winter water use 2. Summer water use	 0.48 0.30
Griffin et al., 1990	**Average water price** 1.Winter water use 2. Summer water use	 -0.16 -0.38
Kiefer et al.,1995	Average maximum daily temperature	1.27 0.81

2.7 CONCLUSIONS

This chapter has reviewed the theory and some recent econometric techniques, which will be used to estimate a model in chapter seven. In addition, it has presented the methodology of the model of water demand and a review of references.

The review of past studies of water use shows a significant number of studies in various categories of water use. Several observations from this review, although somewhat obvious, are worth mentioning. There is much variability in the selection of both dependent and independent variables in water use studies, even within narrowly defined individual water use sectors. Few studies were available for comparison using a single comparable set of variables. The results presented in the articles reviewed here are often contradictory and the values of reported coefficients frequently have signs and values that fail to conform to reason or theory. The availability of studies varies from sector to sector and the differences in data and methodologies used preclude comparisons of results across individual studies. Because of this, the collection of existing studies included here should be viewed primarily as exploratory studies, and demonstrate the value of future, more comprehensive review efforts.

Table (2.1) lists three estimates of income elasticities. All reported elasticities are positive and range from 0.30 to 0.58. (Griffin et al., 1990, Foster et al., 1979, Darr et al., 1975). All price elasticity estimates are negative and range from -0.16 to -0.894. These elasticities indicate that water use is generally inelastic with respect to price (Griffin et al., 1990, De Rooy, 1974, Moore et al., 1963). Table (2.1) also presents several estimates of the elasticity of temperature estimates, which are positive and range from 0.81 to 2.74 (Berk et al., 1980, Kiefer et al., 1995, Berk et al., 1980).

The next chapter provides a description of the Libyan environmental context and, in addition, it presents information about political change.

CHAPTER THREE

THE ECONOMIC ENVIRONMENT IN LIBYA

3.0 INTRODUCTION

The purpose of this chapter is to provide information about developments in Libya with particular relevance to the Libyan economy. Also it will discuss in more detail the economic environment from independence in the1950s until the lifting of UN sanctions in 2003-2004.

This chapter is divided into three sections. Section 3.1 discusses the Libyan environment and provides information about the State's geography, population, language and religion, as well as historical background. Section 3.2 provides an overview and discussion of the political changes. Finally, section 3.3 discusses the economic environment and aspects of Libyan society. Finally, a conclusion to the above discussion is provided in section 3.4.

3.1 LIBYAN ENVIRONMENT

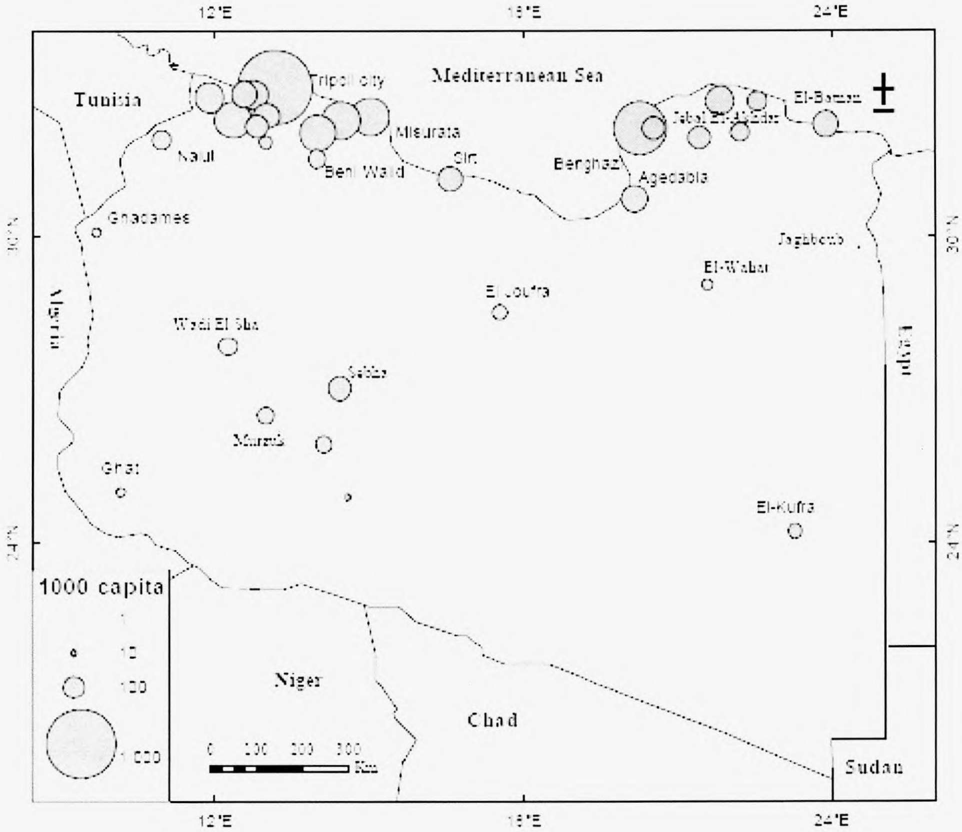
3.1.1 Location

Libya is a North African country that lies on the south coast of the Mediterranean Sea with a coastline of about 1,900 kilometres. Apart from the Mediterranean Sea coast, Libya has frontiers with six Arabic and Africa countries: Algeria and Tunisia in the west, Egypt on the east, Sudan on the southeast, and Chad and Niger in the south. The country has a small population of about 6.09 million inhabitants in 2005 occupying, a relatively large area of about 1,760,000 square kilometres. it is the fourth-largest country in Africa, and seven times bigger than Great Britain and Northern Ireland (Wright, 1969). It is approximately one-half the size of Europe or one-quarter the size of the United States (Bait-Elmal,et al.1973; The Economist Intelligence Unit, 1997-1998). The two largest cities in the country are Tripoli in the west and Benghazi in the east. In the past the country was divided into three administrative regions. These regions were Cyrenaica to the east, Tripolitania in the west and Fezan to the south. More than 90 percent of Libya is desert or semi-desert, consisting of sand areas and two areas of hills and mountains. The mountains are Jable Nafusa in the northwest (south Tripoli) and Jable El-Akdar in the northeast (east of Benghazi). The climate is mostly dry and desert-like in nature. However, the northern regions enjoy a milder Mediterranean climate. Furthermore, a feature of the Libyan climate is the Ghibli, a hot, dry, dust-laden southern wind blowing from one to four days in the spring and autumn.

3.1.2 Population

According to the population distribution in Libya based on 2005 estimates people concentrate on two centres (Figure 3.1): the first, in the northwest (Jifdara plain) where about 60% of all Libyans live, including Tripoli city - the capital of Libya - where more than one million people live, and the second centre in north-eastern Libya (Benghazi plain). The main reasons for this concentration are fertile soils and seasonable, moderate climatic conditions.

Figure (3.1): Spatial Distribution of Population in Libya, 2005



Date source: National Information Authority of Libya, 2005

The cultivable areas are estimated at 3.8 million hectare or slightly over 2% of the area, while the irrigation areas in all Libya were estimated at 400,000 ha (Ben-Mahomed,et al.2000:2). The fertile lands of Jifara plain in the northwest, Jebal Al-Akdar in the northeast and the coastal plain east of Sirt receive sufficient precipitation to support agriculture. As a result, more than 90% of Libyan population resides there. Between the productive lowland agriculture zones lies the Gulf of Sirt that stretches 500 km along the coast, from where deserts extend northward to the sea. Libya's total population was at 5.04 million in 2000 including more than 500,000 non-nationals (Jamahiriya Statistical Book, 2006). In 2004, population estimate was at 6.09 million with a growth rate of

3.50%, birth rate of 26.82 /1,000/years and death rate of 3.48/1,00/year (national information authority of Libya, 2005). Almost 90% of the population lives in the coastal region in the north, and the rest in widely scattered oases in mid- and southern Libya.

3.1.3 Language

Arabic is the official language in Libya. Although legislation requires that all signs and documents be in Arabic, English and Italian are understood by many Libyans and are often used in trade. Tamazight (i.e. .Berber languages) are spoken by Libyan Berbers. In addition, Tuarges speak the Tamahaq language.

3.1.4 Religion

The dominant religion in Libya is Islam (97% of the population). It provides both a spiritual guide for individuals and a basis for all the State's rules and policies. The Constitutional Declaration of the 1969 revolution declares Islam the state religion and guarantees to other religious groups the freedom of practising their religious traditions within the country (Ansell and el-Arif, 1972).

3.1.5 History

The name "Libya" is derived from the Egyptian "Libu" which refers to one of the tribes of Berber peoples who lived in the west of Egypt in the 13th century (Abuarrosh, 1996). In general, the history of Libya has been one of long-time colonisation until 1951-because of its location which made it an easy target for all invaders throughout history - beginning with Phoenicians, Carthaginians, Greeks, Romans, Vandals and Byzantines.

Arabs conquered the country in the 7th century and in the following centuries many of the indigenous peoples adopted Islam and also the Arabic language and culture. Steel (1967, p.101) wrote that:

"With the Arab conquest, beginning in 643 A.D, the history of Libya took an entirely different course. Its culture was changed and so were its language, religion and population. In a few years the Arabs were able to do in Libya and the rest of North Africa what neither the Romans nor the Byzantines had been able to do in centuries".

In about 1530 Tripoli was invaded by Spain for approximately twenty-one years. From the mid 16th century (1551) Libya was ruled by the Ottoman Turks and it remained part of the Ottoman Empire until 1911. In 1911 Italy invaded Libya. Italy gained control of the area following World War I, setting up a new administrative system joining together the country's three main regions (Vandewalle, 1998). These regions were known as Cyrenaica in the east, Tripolitanin in the west and Fezzan in the south. Libya remained as an Italian colony until 1943. In 1934, Italy adopted the name "Libya" (used by the Greeks for all of North Africa, except Egypt) as the official name of the colony.

The Italians improved the infrastructure of the state, creating roads, railroads, port facilities and irrigation projects, but did little to educate and train the inhabitants in administrative, technical or agricultural skills.

After the Second World War, from 1943 until 1951 Cyrenaica and Tripolitania were occupied by a British military administration and the Fezzan region by French forces (Naur, 1986). In 1944, King Idris returned from exile in Cairo. On 24th December 1951, Libya (United Kingdom of Libya) declared its independence under the rule of King Idris of the Sanussi family. He reigned over the United Kingdom of Libya (later in 1963, the name was changed to the Kingdom of Libya) until 1969. When Libya declared its independence, it was the first country to achieve independence through the United Nations (Abuarrosh, 1996).

On 1st September 1969 a small group of military officers (12 people) led by army officer Colonel Muammar Al-Gaddafi overthrew King Idris and designated itself the Revolutionary Command Council (RCC), which formed a new government. In the first declaration on September the 1st, the RCC proclaimed the country to be a free and sovereign state called the Libyan Arab Republic. Gaddafi is referred to as the "Brother Leader and Guide of the Revolution". The new government declared as its slogan "Freedom, Socialism and Unity". In1977 the official name of the country was changed to "the Socialist People's Authority" according to the implementation of "The People's Authority". The term "Jamahiriya" is translated to mean "Power to the masses" (Wright, 1981, P:191).

In 1970, the UK and US military bases in the country were required to be evacuated as soon as possible and they were evacuated on March the 28th (UK) and June the 11th (US) 1970.

During the 1970s Gaddafi produced a book of three parts known as 'The Green Book', setting forth his political, economic and social programmes. The first part (1976) is "The solution of the problem of democracy", the second (1978) is "The solution of the economic problem "and the third (1979) is "The solution of the social problem". His theory focus is the problem of freedom which resulted in rejecting the communist and the capitalist approaches and officially espousing an Arab \socialism that integrated Islamic principles with social, economic and political reform.

In January 1986 the US imposed economic sanctions against Libya because it was accused of being a supporter of terrorism. In April 1986, the US launched an air raid against Libyan targets in Tripoli and Benghazi. On August 5th 1996 the US imposed additional sanctions as part of the Iran-Libya sanctions programme. However, in 2004 the US sanctions were lifted as a response to significant steps by Libya, including abandoning its programmes to build weapons of mass destruction.

On March 31st 1992, the UN Security Council imposed sanctions against Libya for the 1988 crash of the US Pan Am flight 103 over Lockerbie in Scotland. However, in August 2003, Libya agreed to pay compensation ($2.7billion) to the victims' families and cease all support for terrorism and in return, in September 2003, the Security Council formally lifted the sanctions. From 2000 Libya began to make significant policy changes that led to a détente in political relationships with western countries.

3.2 REGULATORY FRAMEWORK

3.2.1 Political Framework

The political regime in Libya during the early 1950s to the late 1960s was parliamentary government. On September 1st, 1969 government authority became the RCC under the leadership of Gaddafi. In 1971 the RCC established the Arab Socialist Union (ASU) as a single political party to encourage the public to participate in political life. However, it failed to achieve its objectives (Abbas, 1987) because this model was inappropriate for the different traditions and culture of the Libyan community (Zuhri, 1978).

In 1973 the radical changes in the Libyan political and economic system were started when Gaddafi gave his speech about what is called the "cultural or popular revolution", which aimed to encourage the public to participate in political life. The tool for implementing this was the creation of "People's Committees". People's committees were functionally and geographically based and became responsible for local and regional administration. In the scope of their administrative and regulatory tasks and method of their members' selection, the people's Committees embodied the concept of direct democracy that Gaddafi declared in the first part of the Green Book.

Further changes were initiated in 1977 when the General People's Congress (GPC) was created to replace the RCC for implementing "The People's Authority". The focus of the new system was the General people's Congress as a legislative body. The GPC still exists today and is headed by a Secretary. The GPC adopts resolutions creating the General Secretariat of GPC and appointing members (i.e. Secretaries or Ministers) of the General people's Committee as an executive body. The General People's Committee acts as the government (the Cabinet).

At its conception, all legislative and executive authority was vested in the GPC, which delegated most of its authority to the General Secretariat and to the General People's Committee. In turn, Municipal People's Congresses (MPCs) which are now known as Sha,biyat People's Congresses (SPCs) and Basic People's Congresses (BPCs) which are now known as Local People's Congresses (LPCs) were established across the country. People debate and take decisions at the LPCs level. These decisions are than passed up to the MPCs and then to the GPC for consideration and setting as national policy. Also, numerous professional associations are integrated in the State structure as a third pillar, along with the People's Congresses and Committees. These associations do not have the right to strike. Professional associations send delegates to GPC, where they have a representative mandate.

Actually, and according to the People's Authority, the Libyan political structure consists of the legislative body and executive Authority which are the GPC and the General People's Committee/Cabinet.

3.2.2. Legal Codes

Governments have participated always in the economic aspects of their societies to maintain full employment and provide security for the people. To achieve these objectives many governmental agencies, commissions and regulation have to be created.

In Libya, laws are promulgated by the GPC, executive regulation and decisions are issued by the General People's Committee and ministerial decisions reissued by the individual secretariats. There are many laws (some of which were reviewed and amended after 1969 to harmonise with the Islamic Sharia) and regulations as there are in many countries. Some of the important laws and important laws and regulations in the Libyan socio- economic environment are: the Civil law, the Commercial Code, Financial System Law, the Foreign Trade Regulations, the Income Tax Law, the Companies Law, the Petroleum Law, The Law of Organising Accounting Profession and the Governmental Accounting Office Law.

3.3 ECONOMIC ENVIRONMENT

Having discussed the social and political aspects of Libya in this subsection the researcher will provide information on the development of the State economic policies from 1951 (year of independence).

3.3.1 Prior to the Discovery of Oil

Libya was one of the poorest countries in the world (Higgins, 1968; Vandewalle, 1998). The country depended on American and British money in return for the use of military bases and aid from the UN and other organisation which helped the country to survive and overcome the economically severe years of the fifties.

During that time the Libyan economy was described as a "dual economy". The first sector was the agriculture and animal husbandry which was the mainstay of the Libyan economy (Higgins, 1968), with about 80% of the workers in this sector of economic activity (Lindberg, 1952) and 20% involved in the manufacturing, marketing and transporting of agricultural crops. The second sector, developed by the Italians, was characterised by companies searching for oil and other technical assistance from abroad to improve Libya's cities (International Bank for Reconstruction and Development, 1960).

The main export was the metals left over from the Second World War (Abbas, 1987).

The Libyan economy was in a bad condition. There were poor production techniques, no skilled labour and shortage of capital and other resources for social and economic development of the country. The per capita income was very low. The country's economy was described by many economists as a deficit economy. There was a deficit in the budget, in the balance of payments and most of the projects also operated at a deficit (Higgins, 1968). The deficits were funded by the Italian government during its colonisation from 1911-1943 (Farley, 1971), the military administrating powers (UK and France) from 1943 to 1952 and since then, by foreign aid and leases of military bases to the USA and UK (Higgins and Jacqres, 1967). Farley (1971, p. 30), the UN's economist, pointed out that the Libyan economy before the discovery of oil was far behind because there was no indication of any economic growth. Higgins (1968, P.27) showed that the Libyan economy faced all the growth obstacles and also clarified that they were political, economic, social and technological obstacles.

3.3.2 After the Discovery of Oil

In 1959, oil was discovered by Esso, a USA company (later renamed Exxon) and production and export of commercial quantities started in 1961 (Wright, 1981; Giurnaz, 1985; Vansewalle, 19998) and as a result the Libyan economic situation changed. The Libyan economy became primarily dependent on the revenues from the oil sector, which constituted practically all export earnings and 70% of the country's Gross Domestic Product[1] (GDP) in 2005.

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1 The development of GDP and per capita income in the Libyan economy is associated with the development in the oil sector, increasing with increase in the oil price and falling with the decline in the oil price.

Table (3.1): Real Gross Domestic Production in Libya by Economic Sectors (At Current Factor Income) in the Period 1965-2005 (In Libyan Dinars/ Millions) [LD approximately = £1.00000 in 1966 and = £2.3280 in 2005

Economic Sector/Years	1965	1970	1975	1980	1985	1990	1995	2000	2005*
Agriculture, Forestry and Fishing	25.2	33.1	82.9	236.4	342.2	482.9	947	1,439.7	1,554.6
Oil and Natural Gas	270.1	812.6	1,961.1	6,525.7	3,500.4	3,243.8	2,468	6,661	38,153.0
Mining and Quarrying	1	1.7	20.7	48.7	49.6	105.5	148.6	313.5	520.0
Manufacturing	12.6	22.5	65.5	210.4	421.7	457.6	799.7	972.9	799.0
Electricity, Gas and Water	2	6.2	17.6	48.7	111.7	152.2	216.7	291.8	379.0
Construction	34.9	87.8	434.7	1,102.3	677.4	457.8	483.9	1,087.1	1,803.0
Trade ,Restaurant and Hotels	25.1	47	224.6	516.9	572.2	789.5	1,254	1,700.3	2,892.0
Transportation, storage and Communication	18.8	43	175.8	420.1	471.8	645.8	892.6	1.252	2,013.0
Banks and Insurance	3.5	13	98.8	246.4	253.7	285.3	286.2	350.3	579.0
Housing	36.4	59.6	131	210.4	250.5	304.6	391	481.3	614.0
General Services (Includes Education and Health	54.3	153.6	432.2	940.4	1,109.9	1,147.7	1,853.3	2,665.8	4,682.0
Other Services	8.5	8	29.3	47.4	91	174.2	307.7	404.5	549.0
(GDP)Distributed between:	492.1	1,288.3	3,674.3	10,553.8	7,852.1	8,246.9	10,048.7	17,620.2	54,537.6
A) Oil and Natural Gas	270.1	812.6	1.961.1	6,525.7	3,500.4	3,243.8	2,468	6,661	38,153.0
b)non Oil Economic Activities	222	475.7	1,713.2	4,028.1	4,351.7	5,003.1	7,580.7	10,959.2	16,384.6
(GDP)Distribution between :%	100	100	100	100	100	100	100	100	100
a)Oil and Natural Gas	54.9	63.1	53.4	61.8	44.6	39.3	31.7	37.8	70
b)Non Oil Economic Activities	45.1	36.9	46.6	38.2	55.4	60.7	68.3	62.2	30

Data source: General Planning Council, 2001a.

Central Bank of Libya, Annual Reports (2001, 2002 and 2003).

*http:/www.cbl.gov.ly/en/listview/index.php

These oil revenues and a small population give Libya one of the highest GDPs per person in Africa (Table, 3.1) and have allowed the State to provide an extensive and impressive level of social security, particularly, in the fields of housing and education. The non-oil sectors, which account for 30% of GDP in 2005 (Table, 3.1), have expanded from processing mostly agricultural products to include the production of petrochemicals, iron, steel and aluminium. The surplus in the balance of payments increased each year becoming the most important source of capital formation. By the way, Libya does not have the capital formation problem which characterised the economies of most development countries. However, the most critical problems for Libya are the high level of inflation, lack of skilled labour, the heavy dependence on the oil sector and the low rate of private capital formation.

Table (3.2): Per Capita Real Income in Libya in the Period 1965-2005 (in Libyan Dinars) Libyan Dinar approximately = £1 in 1966 and = £2.3280 in 2005

Year	**1965**	**1970**	**1975**	**1980**	**1985**	**1990**	**1995**	**2000**	**2005***
Amount	304	656	1369	3251	2169	1822	2224	3247	8927

Data source: General Planning Council, 2001a.
Central Bank of Libya, Annual Reports (47), 2003.
*http:/www.cbl.gov.ly/en/listview/index.php

During the period 1951-1969, the Libyan economic system was mainly capitalist. Private ownership existed with minimum government interference. Public ownership was in sectors that required large scale investment. The government launched a number of measures to encourage competition and the establishment of private business. These included the establishment of the Industrial and Real-

Estate Bank of Libya (currently known as the Development Bank) to provide loans to Libyan businessmen to build local industries, the establishment of the Industrial Research Centre to help implement the country's development plans by providing technical and economic services in both the public and private sectors and new import and export laws demanding that the import of competitive foreign goods be subject to licence (Bait-El-mal et. al. ,1973).

Since 1970, the economy has changed considerably. Several steps were taken by the revolutionary government in order to reform the economic situation and it has changed from a capitalist to a socialist economy. State intervention in the economy has increased and the government started expanding the public sector and reducing the private sector. From the late 1970s up to 1991 the Libyan economy was centrally planned and the State controlled all manufacturing activities, foreign and domestic retail trade and banking and insurance services. However, private companies have emerged and started to operate in Libya from the 1990s. The appearance of private companies was mainly because of the crises that the Libyan economy had faced from the mid-1980s as world oil prices fell (the Economist Intelligence Unit, 1997-1998) the decrease in the General Treasury's revenues from the domestic resources which were reflected in the performance levels and efficiency rates of service and productive enterprises and developments in the international economic environment. Moreover, the Libyan national economy faced technical sanctions (imposed from the US/UN) which hindered the industrial enterprises from importing technology. As a result of these crises, the State introduced a series of economic and political liberalisation measures including a significant role for the private sector.

The main objectives of these measures were to cut public spending and to enhance private sector initiatives in different sectors (Vandewalle, 1998).

The first set of reform measures, adopted in 1985 and 1988, allowed the people to be productive through creating self-management or collective ownership businesses. In 1992, to enhance economic development, the State issued Act Number 9 to regulate and enhance the private sector activities in the national economy and to open the door for the privatisation of a number of public- sector companies. In 1997, the State passed Act Number 5 concerning encouragement of foreign capital investment. As a result, the Libyan economy consists of three major sectors that form its structure, namely, the oil sector, the public sector and the private sector.

Since the early 2000s, the State has made progress on economic reforms as it attempts to rejoin the international community. It has applied for membership of the World Trade Organisation (WTO), many State–run industries are being privatised, the US and UN sanctions were lifted and many international oil companies have returned to the country.

3.3.3 Development Plans

The appearance of oil in commercial quantities encouraged the State to have various economic development plans for either a three-year or five-year period. In 1960 the government constituted the National Planning Council to decide on policies for planning and development and in 1963 the Ministry of Planning and Development to act as an administrative and executive body for these policies (Giurnaz, 1985). The government also decided that a minimum of 70 per cent of oil revenues must be used to finance social and economic development programmes.

This first development plan was approved in August 1963 in the form of a five-year plan for economic and social development (table 3.3). This plan called for an expenditure of LD 169.1 million[2]. However, the annual increase in oil revenues led to an increase in the final amount spent on this plan to LD 551 million, or 325.84% of planned expenditure. This first five-year development plan aimed to accomplish seven major objectives. These objectives were: a) to ensure the improvement of the standard of living of people, b) to give special consideration to the agricultural sector; to pay attention to industry; to improve the productive efficiency of farmer and labourer; and to encourage the private sector to make investments in these filed, c)to allow the public sector to increase its investments in such services as education, health, communication and housing, d) to develop rural areas by establishing productive and public service projects, e) to organise the imports policy, f) to take such monetary, financial and commercial measurements- all in a coordinated effort -as may be necessary to ensure increased revenue and to enforce control on expenditures and g) to take steps to meet the lack of information and statistical data which are necessary for planning (Farley, 1971). Although the development of the agricultural sector was one of the plan's priorities, the performance of this sector was very poor at the end of the plan (Abbas, 1987), however, it recorded some achievements in sectors such as health and education.

[2] The currency unit in Libya is the Libyan Dinar (LD) and the average exchange rates between the LD and the UK pound (£) during the 1962-2005 period ranged from £ 0.35156 to £ 2.3980.

The second five year development plan was approved in May 1967. This plan was designed to allocate more than three times the actual expenditure of the first five-year plan for the period from than April 1969 to March 1974. This plan provides the continuity of the work in the first plan in the fields of transportation, agriculture, public services and housing. In addition, it provided for an industrialisation programme with emphasis on petroleum refining and other light industries. However, this plan was abandoned because of the new revolutionary government in 1969 (Elmaihub, 1981) and was replaced by yearly development plans until 1973. During the period 1970-1972, the state spent LD791 million on economic and social developments. The highest amount was allocated on housing (30.5% of actual expenditure-LD 241 million), than the agricultural sector and industrial sector (17.1% and 13.8% respectively-LD135.1 and LD 109.1 million). From 1973 to 1985 the State approved and implemented three economic and social development plans (1973-1975 plan, 1976-1980 plan and 1981-1985 plan). However, from 1985 to now, there were many attempts to prepare development plans but some of them were not implemented and the others were not completed.

The three-year development plan 1973-1975 was the first plan after the 1969 Libyan revolution. This plan was launched in 1973 and called for an expenditure of LD 1,965 million (Libyan Ministry of planning, 1973). Housing, agriculture, industry, electricity and transportation received the greatest importance and shared roughly equal emphasis in the 1973-1975 plan tables (3.3).

Table (3.3): Socio-Economic Development Plan 1973-1975 (in Libyan Dinars/Millions) Libyan Dinar approximately = £0.68639 in 1973 and = £0.59855 in 1975

Economic Sector	Amount	%
Agriculture, Forestry and Fishing	327.8	16.6
Oil and Natural Gas	48.9	2.5
Mining and Quarrying	2.9	0.2
Manufacturing	231.6	11.8
Electricity, Gas and Water	257.4	13.1
Construction	6.2	0.3
Wholesale and Retail Trade	1.0	0.1
Transportation, and Communication	253.8	12.9
Banks and Insurance	0.4	0.0
Housing	361.3	18.4
public Services (Except Education and Health	1286.7	9.5
Education Services	192.1	9.8
Health Services	71.0	3.6
Other services	0.0	0.0
Reserve	23.9	1.2
Total	1965.0	100

Data source: Ministry of Planning Three- year Socio-Economic Development Plan (1973-1975), p.90

This reflects the State's policies maimed at providing housing for people and making the country self-sufficient in food supplies as soon as possible. In the industrial sector priority was given to areas such as foodstuffs, building material and petrochemical industries (Libyan Ministry of Planning, 1976).

In 1975, the Libyan government allocated LD 7, 170 million to be invested in support of the five-year development plan 1976-1980 (Table, 3.4).

Table (3.4): Socio-Economic Development Plan 1976-1980 (in Libyan Dinars/Millions) Libyan Dinar approximately = £0.4960 in 1976 and = £0.69031 in 1980

Economic Sector	Amount	%
Agriculture and Agrarian Reform	445.3	6.2
Integrated Agricultural Developments	781.3	10.9
Industry and Mineral Resources	1089.7	15.2
Oil and Gas	648.2	9.0
Electricity	543.6	7.6
Transport and Communication	632.1	8.8
Education	470.4	6.6
Health	171.4	2.4
Manpower	41.8	0.6
Social security	43.2	0.6
Housing	794.2	11.1
Economy	32.7	0.5
Sport, Information and Culture	91.3	1.3
Municipalities	552.7	7.7
Planning	56.7	0.8
Reserve	325.3	4.5
Nutrition and Sea Wealth	41.4	0.6
Marine Transport	373.5	5.2
Security Services	35.0	0.5
Total	7170.0	100

Data source: Bearman(1986,p.193).

This plan is considered a continuation of the development policies underlying the previous three- year plan. The main objective of this plan was to ensure diversification and eliminate the dependency of the country upon a one-product economy. In total, the plan aims at attaining self-sufficiency at least in food products, reducing inequality of incomes and wealth and developing the country's limited manpower through expanding training programmes and improving the Libyan educational system (Libyan Ministry of Planning, 1976).

The 1976-1980 development plan was later revised see (Table, 3.5) with more investment going to industry rather than agriculture (Wright, 1981).

Table (3.5): Revised Socio-Economic Development Plan 1976-1980 (in Libyan Dinars/Millions) Libyan Dinar approximately = £0.4960 in 1976 and = £0.69031 in 1980

Economic Sector	Amount	%
Agriculture, Forestry and Fishing	1030.1	14.4
Oil and Natural Gas	41.0	0.6
Mining and Quarrying	9.0	0.1
Manufacturing Industry	1515.4	21.1
Electricity, and Water	706.7	9.9
Construction	7.0	0.1
Wholesale and Retail Trade	32.9	0.4
Transport, and Communication	1197.8	16.7
Housing	887.5	12.4
public Services (Except Education and Health	760.1	10.6
Education Services	513.00	7.2
Health Services	145.2	2.0
Reserve	324.2	4.5
Total	7171.0	100

Data source: Ministry of Planning, socio-Economic Transformation Plan (1976-1980), p.58.

In 1981, the 1981-1985 economic and social transformation plan was launched (Table, 3.6). The 1981-1985 plan allocated funds of LD 17,000 million to different sectors with 23.1 per cent to industry (16.1% heavy industry and 7.0% light industry) and with agriculture coming second receiving 18.2 per cent. Encouraging the development of heavy industry became a high priority for the State in the 1980s the plan aimed to increase non-oil economic activities growth by 10.3%.

Table (3.6): Socio-Economic Development Plan 1981-1985 (Libyan Dinars /Millions) Libyan Dinar approximately = £0.55622 in 1981 and = £0.42885 in 1985

Economic Sector	Amount	%
Agriculture and land Reclamation	3100	18.2
Light Industry	1200	7.0
Heavy Industry	2730	16.1
Oil and Gas	200	1.2
Electricity	2000	11.8
Education	1000	5.9
Information and Culture	150	0.9
Labour Force	150	0.9
Health	560	3.3
Social Security	130	0.8
Sport	100	0.6
Housing	1700	10.0
Public Utilities	1300	7.6
Transport and Communication	2100	12.3
Economy	500	2.9
Planning	80	0.5
Sub-total	17000	100.0
Projects Reserves	1500	
total	18500	

Data source: Secretariat of Planning, Socio-Economic Transformation Plan (1981-1985), p.97

Shortages of foreign exchange for the Libyan government began to emerge as a problem in 1981 because of the drop in oil sales (Bearman, 1986) and with budgets in deficit. Since the mid-1980s, Libyan oil revenues had fallen to their lowest level since the first Organisation of Petroleum Exporting Countries (OPEC) price shock in 1973 and as a result development spending has declined.

The fall in oil prices accompanied by the US sanctions and the UN sanctions which cost Libya approximately $34 billion contributed to the difficulties the economy encountered.

At the beginning of 1994, the State launched a three-year programme covering the period 1994-1996. The programme's main goals were: settling the debts of previous development projects; completion of existing projects, especially in health, education, public utilities and energy sectors; encouraging investment in production sectors, especially industry, whether through the public or re-emerging private sectors, stopping all projects that had not started yet (the Secretariat of Planning, Trade and Treasury, 1993). However, this programme was abandoned with a few of its goals achieved (Table, 3.7)

Table (3.7): Three Years Programme 1994-1996 (Libyan Dinars/Millions) Libyan Dinar approximately = £0.56378 in 1994 and = £0.60712 in 1996

Economic Sector	Allocation	Actual Investment	Percentage of Actual Expenditure of Each Sector to total (%)	Percentage of Actual Investment to Allocation (%)
Agriculture	158	49.130	3.4	31
Industry Energy Education	49.700	132.8	9.1	140
Energy	332	371.5	25.6	111
Education	289	127.900	8.8	44
Media & Culture	12	5	0.3	41.6
Health & Social Security	205	87.9	6.1	42.8
Transport	194.700	66.050	4.6	34
Planning	17.900	10.800	0.7	60
Economic	6	1.975	0.1	33
Sea Resources	25.600	15.850	1.1	62
Justice & General Security	12.300	6.200	0.4	50.4
Administration Centres	240	271.911	18.7	113
Human Resource	32	32.00	2.2	100
Housing & Public Utilities	297.450	140.400	9.7	47
Tourist	3	2.400	0.2	80
Animal Resources	11	8.250	0.6	75
Man-Mad River	100	20	1.4	20
Finance	5	0	0.0	00
Previous Commitments	100	33	2.3	33
Reserve& Maintenance	264.350	67.500	4.7	25
Total	2400	1450.566	100	60.44

Data source: Secretariat of Planning, Economic and Trade, (1997): The Follow up Report of Implementation of the Three-Years-Programme (1994-1996).

The total amount allocated to the 1994-1996 period was LD 2,400 million of which only LD 1,450.556 million, or 60.44% of the total allocation, were actually invested.

The increase of the private sector role in the Libyan economy and the concentration on improving the economic performance became one of the economic policy priorities from the early 1990s and this occurred in several places in the presentation of the five-year social and economic plan 2001-2005. In 1999 the State started to prepare a five-year plan 2001-2005 economic and social transformation plan, which later was adjusted to 2002-2006 economic and social transformation plan according to the reform of the Libyan economy. This plan was for LD 36 billion with the oil resources contributing 45% of the total and the contribution of the foreign and national domestic sectors was estimated at 57% of the total (Al-Zini, 2002).

This new style of planning the role of the State in the creation of the appropriate economic environment, through the introduction of institutional and administrative changes. The difference between this plan and the previous plans is that the later one gives a very important role for the national and foreign private sector in financing and implementing the productive and service enterprises while the State assumes its role is to finance and implement the infrastructure and service projects. However, the approval and implementation of this plan was delayed for several reasons, the most important being the high level of liabilities of previous development plans, the size of the plan's expenditure and the international and domestic economic development that the national economy faced (AL-Zini, 2002).

The banking sector had a significant role in the growth of Libyan economy, where it provided the finance and helped the various economic sectors through its banks by offering loans, opening documentary credits, selling and paying foreign currencies and discounting bills of exchange.

3.3.4 The State's Budget

In Libya the budget is divided into two main parts which are an administrative budget and a development budget. The Secretary of Finance organises the budget which is then discussed by the Basic People's Congresses and finally approved by the GPC. The administrative budget includes the revenue and expenditure of the secretariats and the transfers to municipalities and public enterprises. Initial proposals for the administrative budget begin at the municipal level and are then forwarded to the specialised secretariat for consolidation and then submitted to the Secretary of Finance, who reviews and forwards this proposal to the GPC for final approval.

The government budget sets out an annual project expenditure programme. This programme is sometimes set within a framework of a three-year plan(e.g. the 1973-1975 development plan, the 1994-1996 programme)or five year plan(e.g. the 1981-1985 economic and social transformation plan)the development budget is initially prepared by organisation and companies that would implement specific projects. These proposals are than sent to the Secretary of Finance, the Secretary of Economy, Trade and Investment and the Secretary of Planning for revisions and submission to the GPC. However, the Secretary has the authority to either approve or modify the organisations' and companies' budgets according to many factors especially the availability of foreign exchange. Foreign exchange in

Libya is strictly controlled by the State through the Central Bank of Libya (CBL) but, the process of budget execution in influenced by the changes in the oil price.

3.4 CONCLUSIONS

In this chapter a general description was given of the Libyan social, political, regulatory and economic environment. The history of Libya from the colonisation of Libya to the Revolution is described. The discussion then explored the political and regulatory context. The Libyan Revolution has introduced a new political system based on democracy and then Libya was governed by the GPC and the General People's Committee. The economic system also has changed to a socialist economy since the late 1970s. This new socialist philosophy has affected the economy in terms of the ownership of economic activities and in the way of planning, managing and controlling economic enterprises' objectives. The Libyan economy still depends heavily on the oil revenues. The State's development plans after the revolution were directed towards reducing the dependency on oil revenues by developing the agricultural and industrial sectors in order to achieve self-sufficiency in food production.

The next chapter introduces the determinants of population growth as well as birth rate, death rate and immigration rate.

CHAPTER FOUR

POPULATION GROWTH AND ITS DETERMINANTS

4.0 INTRODUCTION

The study of population growth and the factors determining it are among the most important issues facing the world today.

This chapter has four sections. Section 4.1 discusses the trends in population growth. Section 4.2 introduces the determinants of population growth as well as the birth rate, death rate and immigration rate. Section 4.3 focuses on population density and is followed by a discussion on population growth in urban and rural regions in section 4.4. Finally, section 4.5 summarises the main conclusions of this chapter.

4.1 TRENDS IN POPULATION GROWTH

The human resources factor is very important for the economic development of any country as a whole and for the development of any sector, organisation and profession within that country. This is due to the fact that it is much easier in many cases to import capital from abroad rather than importing human resources. The available data and information about population in Libya indicates that the rate of population growth is considered very high, one of the highest rates of population growth in the Arabic countries (see Table 4.1).

Table (4.1): Trends of Population Growth in the Arabic Countries in 2005 (Selected Countries)

Country	Growth Rate %	Birth Rate: Birth/1.000 Population	Death Rate: Death/1.000 Population
Libya	3.50	26.82	3.48
Kuwait	3.44	21.88	2.42
Iraq	2.70	32.5	5.49
Sudan	2.60	35.17	9.16
Jordan	2.56	21.76	2.63
Syria	2.34	28.29	4.88
Saudi Arabia	2.31	29.56	2.62
Egypt	1.78	23.32	5.26
U A E	1.54	18.78	4.26
Bahrain	1.51	18.1	4.08
Tunisia	0.99	15.5	5.09

Data source: http://www.photius.com/rankings/population/population_growth_rate_2005_0.html

As you shown in Table (4.1) Libya has one of the highest rates of population growth in the Arabic countries. In 2005 data indicate that the population growth in Libya is 3.50%. Libya population grew at an average rate of 3.50%, averaging more than 3 percent annually for much of the second half of the 20th century. The huge influx of foreign workers into the country since the 1960s accounts for part of this rapid growth, but Libya's annual rate of natural increase (birth rate minus death rate) has also been one of the highest averages in the world for much of the late 20th century. Death rates have declined to near the world average, but birth rates remain high. Table (4.2) shows that almost one-half of the population is 15 years of age or less despite high rates of infant mortality, implying continued high birth rates and rapid growth well into the 21st century.

Table (4.2): Age Categories in Libya

Age Categories	2000	2005
0-4	526035	536552
15-19	709554	870341
45-49	142085	161803
Above 75	62637	68676

Data sources: Jamahiriya Statistical Book, the National Corporation for Information and Documentation, 2006,1996,1986,1976

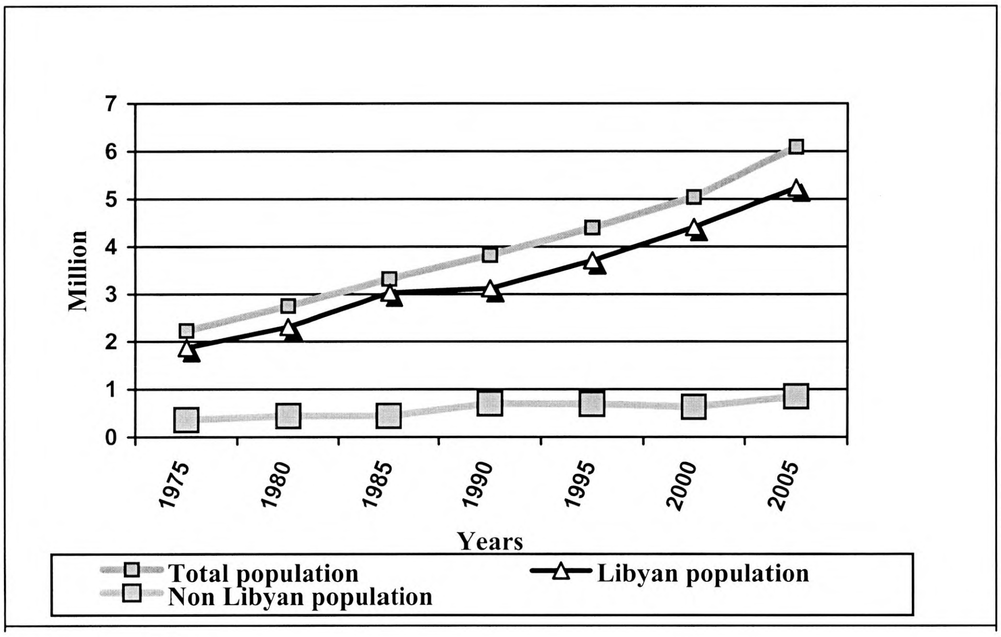
Table (4.3): Libyan and Non-Libyan Population Growth during the Period 1975-2005

Years	Total Population Million	Libyan Population Million	Non Libyan Population Million	Libyan Population Rate to Total Population %
1975	2.23	1.87	0.36	83
1980	2.75	2.31	0.44	84
1985	3.32	3.03	0.29	91
1990	3.82	3.12	0.70	81
1995	4.40	3.71	0.69	84
2000	5.04	4.41	0.63	88
2005	6.09	5.24	0.85	86

Data sources: Jamahiriya Statistical Book, the National Corporation for Information and Documentation, 2006,1996,1986,1976.

Great Socialist People's Libyan Arab Jamahiriya, General Authority for Information and Communication, Statistics Book, General Authority for Information and Communication Yearly Bulletin, 2004.

Figure (4.1): Libyan and Non-Libyan Population Growth during the Period 1975-2005



Data sources: table (4..3)

By reviewing the data in table (4.3) and figure (4.1), the following can be noticed:

- During the period 1975-2005, there has been a rapid growth in the Libyan population from 1.87 million to 5.24 million. During the same period the non-Libyan population increased from 0.36 million to 0.85 million.
- The total population in 2005 is 6.09 million giving the country an overall population density of 3.2 persons per square kilometre. Approximately 90% of the people live in the main cities, while the rest live in the countryside.
- The 2005 census showed that the majority of the population are in their middle age and the rate of illiteracy declined to 12%, while the rate of university graduates rose from 3% to 13% over the period under review.

The population in Libya has doubled during the period 1975 to 2005, increasing from 2.23 million in 1975 to 6.09 million in 2005.

The Libyan population has increased from 1.87 million in 1975 to 5.24 million in 2005. During this period the ratio of Libyan population reached 86% and the annual average rate of Libyan population growth reached 3.5%.

By following the phases of population growth during the period 1975-2005, it is noticeable that total population growth has increased, while the annual rate of Libyan population growth has decreased. The decrease in the rate of total population growth during the period 1975-2005 is due to the decrease in non-Libyan population in the same period.

The great expenditure for different investments related to economic activities since the early seventies has led to demand for labour outstripping the supply of Libyan workers. That led to making use of non-Libyan work force (Arabs and foreigners), which resulted in increasing the non- Libyan population.

Though the non-Libyan population has decreased in the mid-eighties as a result of the procedures taken for decreasing the number of non-Libyan, the non-Libyan population has generally increased.

As in most developing countries Libya's population is quickly growing. Starting with less than 1 million inhabitants after a devastating African Blitzkrieg 1941-1943, the present population in 2005 is estimated to be around 6.09 million. A simple ratio of the population to the country's land surface would give a density of 2.5 inhabitants per square kilo metre.

The problem of rapidly increasing population in Libya leads to pressures on the fragile and vulnerable soils translating into overexploitation of water land and pasture resources through over-cultivation, overgrazing, deforestation and poor irrigation practices. The resulting erosion and degradation of productive lands has led to food insecurity. An increasing water demand for social, agricultural, and industrial developments has accelerated groundwater deterioration.

4.2 DETERMINANTS OF POPULATION GROWTH

4.2.1 Birth Rate[1] in Libya

The main factor of population growth is the birth rate-mortality balance in the society. Whenever the birth rate is high and mortality low, the population grows. The tendency of a decrease of the birth rate in recent years is explained by the decrease in the rate of fertility due to the greater role played by women in the labour market, increasing marriage expenses, as well as the spread of education and public culture among members of society. The final results of the 2005 census show that:

The rapid population growth results partly from high fertility (44 birth p.a/ 1,000 inhabitants) and low mortality rates (9/1,000), and partly from an influx of foreign workers, notably from neighbouring countries (Egypt, Tunisia, Chad). Forming more then 20 per cent of the manpower, they work mainly at menial jobs but also partly run the administration and the more sophisticated production sector.

[1] Birth rate =total of live births/total of population x1000

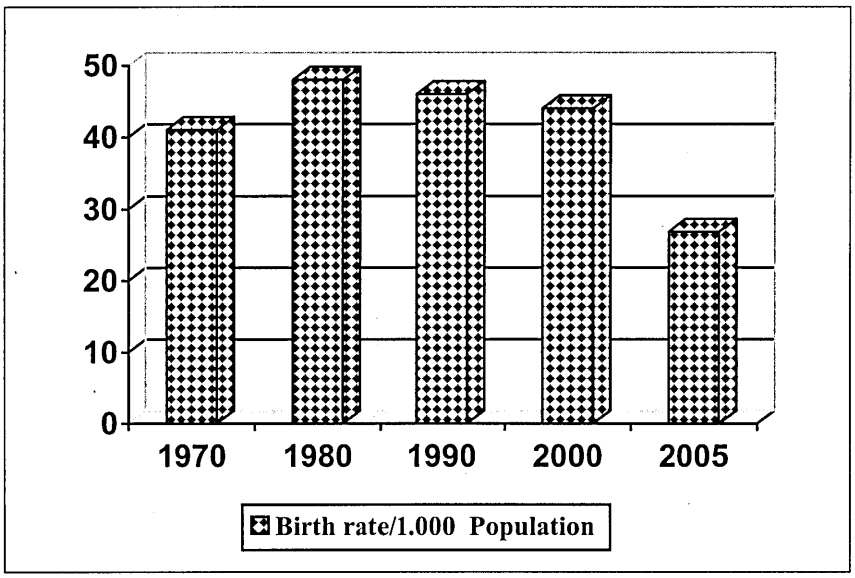
Table (4.4): Birth Rate during the Period 1970-2005

Year	Birth Rate/1.000 Population
1970	41.0
1980	48.0
1990	46.0
2000	44.0
2005	26.82

Data sources: Jamahiriya Statistical Book, the National Corporation for Information and Documentation, 2006,1996,1986,1976

Great Socialist People's Libyan Arab Jamahiriya, General Authority for Information and Communication, Statistics book, General Authority for Information and Communication Yearly Bulletin, 2004

Figure (4.2): Birth Rate during the Period 1970-2005



Data sources: table (4.4)

4.2.2 Death Rate [2](Mortality) in Libya

Despite non-availability of detailed data about natality in the Libyan Jamahirya, it is remarkable, that mortality increases in the first year of age, then collapses sharply after the first year of age up to the fifteenth year of age. After that it gets higher gradually up to the fortieth year of age. After this age it increases rapidly.

In the table (4.5) and figure (4.3) showing mortality it is noted during the period 1975-2005 that the improvement of living standard (nutrition, dwelling, sanitary services) has decreased the mortality from 9.2 /1.000 in 1970 to 3.48 /1.000 in 2005.

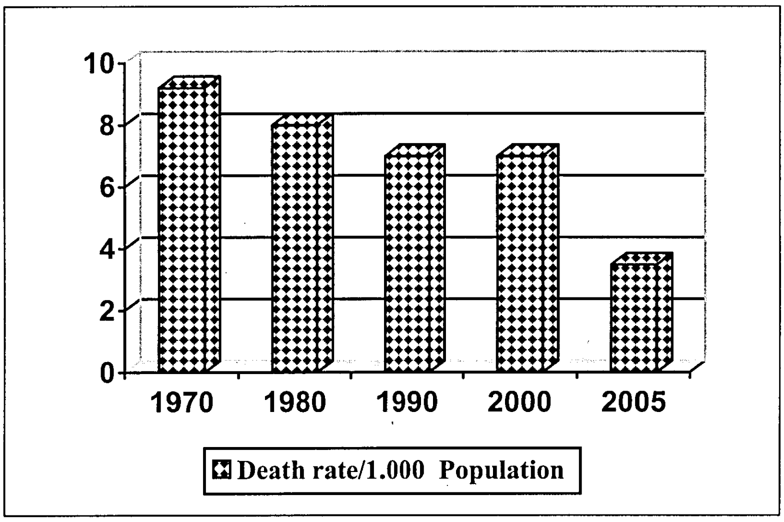
Table (4.5): Death Rate during the period 1970-2005

Year	Death Rate/1.000 Population
1970	9.2
1984	8.0
1990	7
2000	7
2005	3.48

Data sources: Jamahiriya Statistical Book, the National Corporation for Information and Documentation, 2006,1996,1986,1976. Great Socialist People's Libyan Arab Jamahiriya, General Authority for Information and Communication, Statistics Book, General Authority for Information and Communication Yearly Bulletin, 2004.

[2] Death rate =total of death/total of population x 1000

Figure (4.3): Death Rate during the Period 1970-2005



Data sources: table (4.5)

4.2.3 Immigration Rate[3] in Libya

In addition to the birth rate and mortality rate as determining factors of population growth, migration and immigration also play an important role on the rate of population growth.

As previously mentioned, the increase of investment in the different economic activities since the early seventies as well as the increase of demand regarding work force and inadequacy of Libyan work force to fulfil the said demand led to making use of non- Libyan work force (Arab and foreign). That was accompanied by an increase of the non-Libyan population as shown in Table (4.3).

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[3] Immigration rate = number of immigration/ total of population x 1000

4.3 POPULATION DENSITY

Libya has the fourth largest area among Arab countries. In spite of that its population density is considered low, if compared with the size of the population. In 2005, for example, the population density of Libya did not exceed an average of 3 person / square kilo metre.

It is worth mentioning here that despite the low population density in Libya in general there is a difference in the distribution of the population from one region to another as a result of the agricultural and industrial development.

As shown in Table (4.6), there are regions where population density is high, while others have low density. The regions located in the north of the country are distinguished by a high population density, while the interior regions and vast desert areas are distinguished by a low population density.

The concentration of population in the northern regions is due to the abundance of rain, good quality of the soil and moderate climate.

In this regard, it is noticeable, that there is a strong relation between high population density and agriculture. A clear example of that is the high density in the districts of Tripoli and Benghazi because of the productive soil and abundant rains there.

Libya has a small population in a large land area. Population density is about 50 people per square kilo metre. (80/ square kilo metre) in the two northern regions of Tripoli and Benghazi, but falls to less then one person per square kilo metre. (1.6/ square kilo metre) elsewhere. Ninety percent of the population live in less than 10% of the area, primarily along the coast. More then half the population is urban, mostly concentrated in the two largest cities Tripoli and Benghazi.

The average population density of about 3 inhabitants/square kilo metre varies between 50 inhabitants/ square kilo metre in the northern regions to less than 1 inhabitant/km^2 elsewhere. In 2005, 54 percent of the Libyan population lived in the western coastal area (Jifarah plain and Misratha area). The eastern coastal area (Al Jabalal Akhbar) is the second area of population concentration with 21 percent. This means that 75 percent of the population is concentrated in 1.5 percent of the total area of the country.

Table (4.6): Population Density in Cities during the Period 1995-2005

City	Area- km^2	1995		2000		2005		Rate of Pop to Total Pop in 2005 (%)
		pop	den	pop	den	pop	den	
Tripoli	3190	987713	309,6	1083151	339,2	1149957	360,49	31.6
Benghazi	14770	500120	33,86	578003	39,13	636992	43,13	17.7
Almirgb	24490	251377	10,26	295739	12,08	328292	13,41	9.0
Sirte	385350	102885	0,36	131392	0,34	156389	0,41	4.3
Alzzawya	4740	156248	32,96	180360	30,05	197177	41,59	5.4
Aljabel Alakhdder	34960	152232	8,18	176601	5,05	194185	5,55	5.3
Alnnikat Alghames	70300	166067	2,36	191381	2,72	208954	2,97	5.7
Sabha	112590	93688	0,83	112743	1,00	126610	1,13	3.47
Albitnan	94210	116106	1,23	132922	1,41	452714	4,81	12.42
Wadialhaya	104590	51602	0,49	63813	0.61	72587	0,69	1.99
Muzeq	339730	52368	0,15	60824	0,18	68718	0,20,	1.89
Alkofra	500630	35091	0,07	44522	0,09	51433	0,10	1.41
Total		2665497		2949981		3644008		

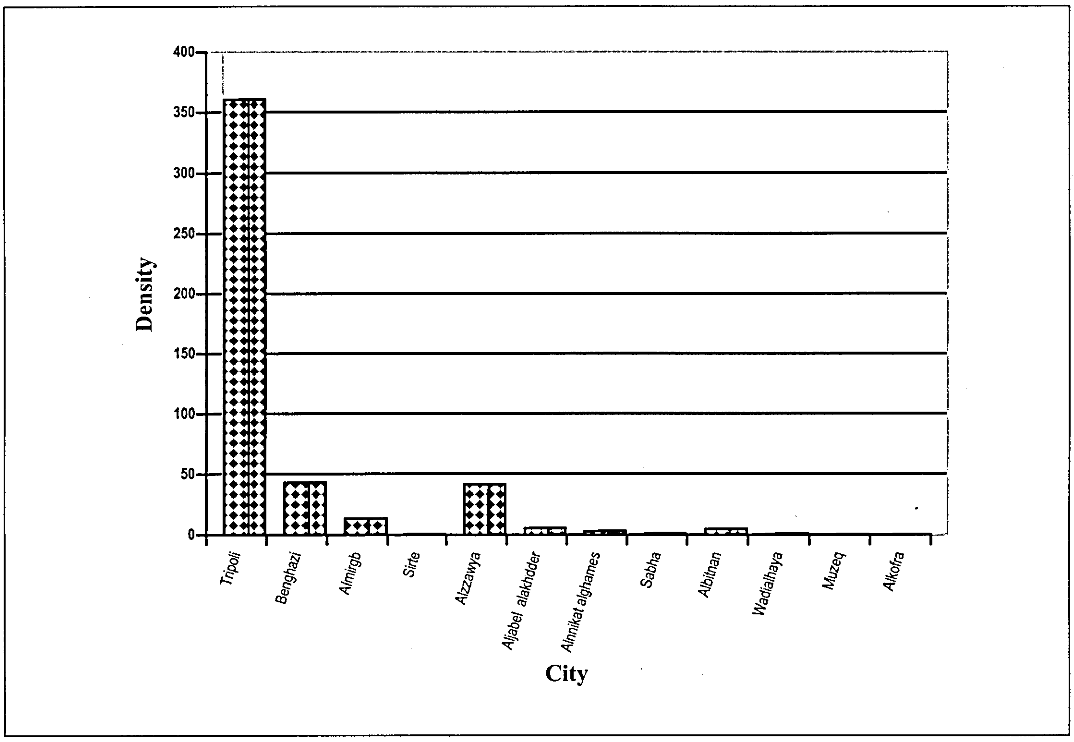
Data sources: Jamahiriya Statistical Book, the National Corporation for Information and Documentation, 2006,1996,1986,1976

Great Socialist People's Libyan Arab Jamahiriya, General Authority for Information and Communication, Statistics Book, General Authority for Information and Communication Yearly Bulletin, 2004.

In addition to the above explanation in regard to the characteristics of the population density in the Libyan Jamahiriya, it is useful to give some attention to the data shown in Table (4.6):

- There is no equality in the distribution of population in Libya, more than 50% of the total population live only in three regions, namely in Tripoli, Benghazi and Zawia (2005).
- The population rate in some low population density areas increased in 2005 while such rate decreased in areas with high population density in Tripoli, Benghazi and Zawia. That is because the process of economic and social development has included a lot of cities and villages in addition to the large cities. Due to that such cities and villages have become centres of attraction for many migrants coming from other regions or those who abandoned them previously. That means that such changes have driven the interior migration movement including the reverse migration from Tripoli, Benghazi and Zawia to other municipalities.

Figure (4.4): Population Density per Square Kilo Metre in Cities in 2005



Data source: table (4.6)

The increase in population of Tripoli and Benghazi is a major force for settlement expansion on agricultural lands. Emigrations from the rural to the urban areas, especially in case of Tripoli city, exacerbate desertification; emigrated people prepared their land to agriculture clearing its vegetation and leaved it without adequate farmers, then it experiences to erosion and degradation. Modern societies may also threat the dry lands in many ways; they need roads and highways, constructing pipelines and canals, establishing factories, and buildings.

4.4 DEVELOPMENT OF POPULATION GROWTH IN URBAN AND RURAL REGIONS

The distribution of the population into urban and rural stipulates, according to the definition approved for censuses done in the Libyan Jamahirya, that the interior regions within the cities are considered urban regions and all others are considered rural areas.

The data shown in table (4.7) indicate that the rate of urban population has increased from 76.7% in 1985 to 89 in 2005, while the rural population has decreased from 23.3% in 1985 to 11% in 2005. And in spite of the fact that the absolute number of urban population during the period 2000-2005 has increased from 5.5 millions to 6.6 millions, the rate of urban population has decreased slightly from 12.4% to 11%. As a consequence the rate of urban population has increased slightly from 87.6% to 89% during the same period indicated above.

The data shown in table (4.7) show that the rate of urbanisation has slightly increased.

In an originally rural country where, in 1964, 25% of the population were still nomads and only 26% lived in towns, the picture has changed dramatically. Nearly 70% of Libyans today hire in urban settlements, with more than 40% of the total in Tripoli as the prime city. The importance of agricultural activities has diminished greatly and it employs now only 20% of the economically active population (in 1986).

The Libyan population is mainly urban: the census of 2005 showed that 89% of the population concentrated in cities. The Libyan cities are confronted, as precised before, with problems of scarcity and quality of water; the problem related to quality of water is caused by excessive extraction of underground water resources, essentially the extraction in the water sheets near the coast, where the salt water intrusion condemns gradually the wells. The large cities, located for the majority in coastal zone, know problems of drinking water shortage, problem for which a solution is undertaken consisting of a transfer of water, known as "the large Artificial River", and of sea water desalination plants: we point out that Libya launched a large programme of sea water desalination plants for a capacity production of one million cubic meters.

As mentioned earlier, population and urbanization in Libya increased sharply in the second half of the 20th century and impacted on natural resources and the environment (water and soil) which are very vulnerable to climate change. Over 90% of Libya's population resides along a mild thin strip on its 1,900 km long Mediterranean coast which also contains the country's most fertile lands and its major industrial projects (Abufayed and EL-ghuelm, 2001: 48).

Because of the vast oil wealth of Libya, significant improvements in the standard of living can be observed. Population is unevenly distributed across the country (2000): 89 % live in urban areas, mostly on the coast. Some of Libyan's people still live in nomadic or semi-nomadic groups in the plains and desert. Urban population in Libya increased from 76.7 % in 1985 to 89 % in 2005 (Table 4.7 and figure 4.5).

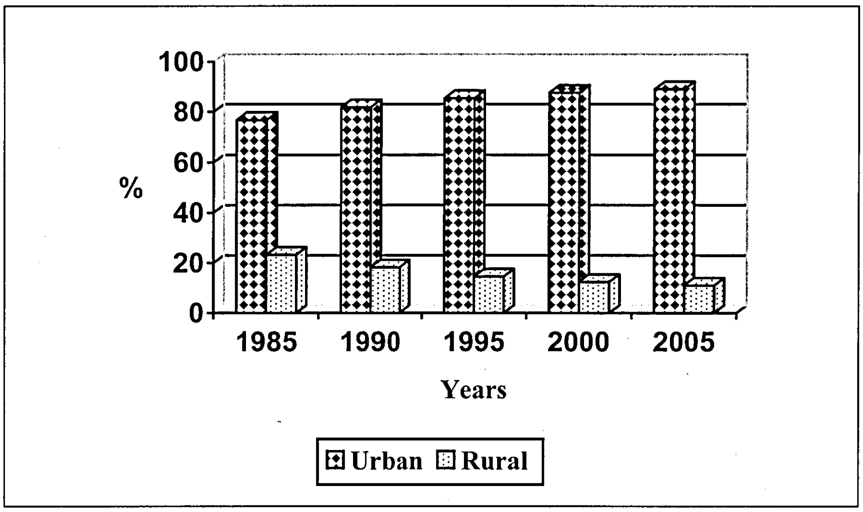
Table (4.7): Population Distribution in Urban and Rural Regions

Year	1985		1990		1995		2000		2005	
Population	Number Million	%	Number Million	%	Number Million	%	Number Million	%	Number Million	%
Urban	2.902	76.7	3.719	81.8	4.615	85.4	5.597	87.6	6.671	89.0
Rural	884	23.3	826	18.2	792	14.6	790	12.4	824	11.0
Total Population	3.786	100	4.545	100	5.407	100	6.387	100	7.495	100

Data sources: United Nation Education Scientific and Culture Organization (UNESCU) Institute for Statistics 2005. World Education Indicators. Paris UNSCO.

United Nations, 1993: Statistical Yearbook, 38: 71; UN, 2002: Statistical Yearbook, 46: 46

Figure (4.5): Population Distribution in Urban and Rural Regions in 2005



Data source table (4.7)

4.5 CONCLUSIONS

In this chapter a general description was given of the trends in population growth, determinants of population growth, population density and development of population growth in urban and rural regions.

Also in this chapter a description of the Libyan and non Libyan population were discussed.

The discussion revealed that, firstly, in the period from 1975 to 2005, there has been a rapid growth in the Libyan population and the non-Libyan population from 1.87 million to 5.24 million and from 0.36 million to 0.85 million respectively. The problem of rapidly increasing population in Libya, lead to pressures on the fragile and vulnerable soils translating into overexploitation of water. Secondly , there is no equality in the distribution of population in Libya, more then 50% of the total population live only in three regions, namely in Tripoli, Benghazi and Zawia . This means that there are regions located in the north country where population density is high while others located in the south country have low density. Finally, the rate of urban population has increased while the rate of rural population decreased.

A discussion of water supply in Libya follows in the next chapter.

CHAPTER FIVE

WATER SUPPLY

5.0 INTRODUCTION

Water sources can be classified as conventional and non-conventional. Water sources are usually divided into renewable conventional sources, such as the surface water of the beds of Jifara and Al jabal Alakhder, and non-renewable conventional water sources, such as the beds of Kufra and Sarir in the south-east. Non-conventional water sources include desalination plants and purification reuse plants of drainage waters.

This chapter discusses the different sources of water in the Libyan economy. It is divided into three sections. Section 5.1 discusses conventional water sources. Section 5.2 focus on the non-conventional water sources. Finally, the factors affecting the water supply are discussed in section 5.3.

5.1 CONVENTIONAL WATER SOURCES

Because it has practically no renewable water sources, Libya relies heavily on groundwater for satisfying its ever-increasing water needs, with minor contributions from springs, wadis, surface runoff and dams.

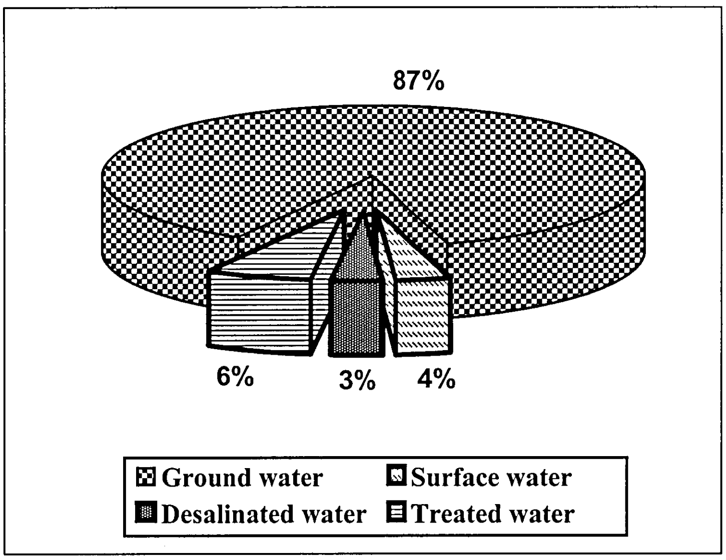
Conventional water sources are divided into two main types: surface water and underground water

Table (5.1): Total Water Sources during the Period 1975-2005

Data Source	Underground Water		Surface Water		Desalination Water		Distillation Water		Total	
Year	Quantity	%	Quantity	%	Quantity	%	Quantity	%	Quantity	%
1975	1739	98	18	1.0	15	0.8	9	0.5	1781	100
1980	2737	97	38	1.4	19	0.7	31	1.1	2825	100
1985	4300	94	81	1.8	25	0.6	165	3.6	4572	100
1990	4655	92	111	2.2	30	0.6	249	4.9	5045	100
2000	4268	88	145	3.0	145	3.0	291	6.0	4850	100
2005	3430	87	120	3.1	135	3.4	250	6.4	3935	100

Data source: General environmental authority, 2002 ,2005 Al-Ghariani, S.A., 1997. "Managing Water Scarcity through Man-Made Rivers." Proceedings of the 27 IAHR Congress on "Water for a Changing Global Community." August 10-15, San Francisco, California, USA, 1997.

Figure (5.1): Water Sources in Libya 2005



Data source: table (5.1)

5.1.1 Surface Water

This is the rainwater which represents the main source of valleys and wellheads. It is considered one of the water sources in the northern areas of Libya. It makes no more than 3% of the total available water sources in Libya as shown in table (5.1). It means also inland waters, except groundwater.

The utilization of surface water is done by holding it behind dams in order to realize many goals, such as:

- Regular irrigation of agricultural crops.
- Keeping soil in good condition and protecting it against erosion.
- Protecting cities against floods.
- Feeding of groundwater reservoir beds.

However, surface water sources are very limited in Libya and contribute about 3% in 2005 of the current water sources in use (table 5.1). This is due to the fact that Libya has no perennial rivers, with surface runoff limited to short winter floods following intense rain storms. Such flow is estimated at around 80 million cubic metres /year in Jabal Akhdar, 77 million cubic metres year in Jabal Nafusa and 30 million cubic metres /year in the Hamada area (Water Sources Management, 2000).

Heavy rainfall events, though not very frequent, can produce major floods in the winter months of October to February. They play a major role in the replenishment of the Quaternary and Tertiary aquifers in northern Libya, and in maintaining the flow of several small- and medium-sized springs.

Libya has in the past few years managed to control a great part of its surface runoff. Hundreds of small dams and reservoirs have been constructed to harvest rainwater and for soil conservation. For flood control and protection of population centres and agricultural fields, 16 major dams were also constructed.

The total reservoir capacity of these dams is in the order of 300 million cubic metres but their average annual storage capacity is only 60 million cubic metres. Water stored behind these major dams is used for the supply of agricultural areas, industrial projects, and, in a few cases, for domestic use (General Environmental Authority, 2001:50).

Some 20 more dams are planned for construction during the coming years, which will raise the annual storage to around 110 million cubic metres.

Surface water sources are not expected to add considerably to the water supply of Libya. In fact if we consider that only that portion of the surface runoff that reaches the sea as a "loss," then even the planned projects, such as the additional dams and reservoirs, will contribute only little to the overall water balance.

Overall, surface water sources are limited and contribute only a small amount to the total water consumption.

5.1.1.2 Rainfall Water

Rainfalls play an important role in affecting an increase/decrease of groundwater reservoir beds, and rains are the main source for feeding water reservoir beds. Rain water could be collected and used by means of dams and valleys. Rainfalls in Libya are considered storm rains falling in periods. The rainfall average varies from year to year. The coastal strip area along the Mediterranean Sea has the highest rainfall average among the Regions of Libya. It is generally known, that the rainfalls become less when we move away from the sea shore towards the south.

Rainfall in Libya varies between 150 and 450 millimetres yearly (Water Sources Management, 2000).

In order to utilize rainwater for the above mentioned purposes, man made dams and reservoirs have been built to hold back valley waters.

In Libya rainfall (56 millimetres) generates an annual average flow evaluated to be 98,000 million cubic metres, but only a small proportion of this rainfall is transformed into renewable water sources, globally evaluated to be 1075 million cubic metres, with 200 million cubic metres for surface water, and 87 million cubic metres for ground water (Water Source Management 2000).

Annual rainfall in Libya is extremely low, with about 93 percent of the land surface receiving less than 100 millimetres/year. This means the most arable land lies in two places: the Jabal al Akhder region around Benghazi, and the Jifarah plain near Tripoli. The highest part of the Jabal Al Akhdar receive between 400 and 600 millimetres of rain annually, whereas the immediately adjacent area, sloping north to the Marj plain, receives between 200 and 400 millimetres. The central and eastern parts of the Jifarah plain and the nearby Jabal Nafusah also average between 200-400 millimetres of rain annually. The highest rainfall occurs in the northern Tripoli region (Jabal Nafusah and Jifarah Plain) and in the northern Benghazi region (Jabal al Akhdar), these two areas being the only ones where the average annual rainfall exceeds the minimum value (250-300 millimetres) considered necessary to sustain rain fed agriculture. Rainfall occurs during the winter months, as can be seen from tables (5.2), (5.3), but great variability is observed from place to place and from year to year.

Less than 2 percent of the national territory receives enough rainfall for settled agriculture, the heaviest precipitation occurring in the Jabal al Akhdar zone of

Cyrenaica, where annual rainfall of 400 to 600 millimetres is recorded. All other areas of the country receive less than 400 millimetres, and in the Sahara 50 millimetres or less occur. Rainfall is often erratic, and a pronounced drought may extend over two seasons. For example, epic floods in 1945 left Tripoli under water for several days, but two years later an unprecedentedly severe drought caused the loss of thousands of head of cattle (Water Source Management 2001).

Table (5.2) Seasonal Averages of Rainfall Depths and Volumes

Season	Average Depth (Millimetres)	Average Volume ($\times 10^6 m^3$)
Winter	72.800	274.389
Spring	26.100	84.228
Summer	0.613	2.560
Autumn	25.700	71.890

Data source: Water Sources Management 14:405-416, 2000 2001 Kluwer Academic publishers. Printed in the Netherlands automated average areal rainfall calculation in Libya

Table (5.3): Monthly Averages of Rainfall Depths and Volumes

Months	Average Depth (Millimetres)	Average Volume ($\times 10^6 m^3$)
January	28.2	97.400
February	12.7	64.889
March	16.2	47.684
April	4.4	16.564
May	5.5	19.980
June	0.41	1.600
July	0.03	0.160
August	0.17	0.800
September	2.9	9.060
October	7.13	23.230
November	15.7	39.600
December	28.9	112.12

Data source: Water Sources Management 14:405-416, 2000 2001 Kluwer Academic Publishers. Printed in the Netherlands Automated Average Areal Rainfall Calculation in Libya

5.1.1.3 Wellheads Water (Valleys)

There is in Libya a number of natural wellheads (about 45 wellheads) in addition to the wellheads of Tawrgha, Kaam, Zayana, Dabbusia and Derna, which have low productivity of no more than Litre/second.

Some of the wellheads have been exploited for providing the water needs of some cities, such as potable water of Derna from Bilad wellhead, potable water of Barce from Dabbusia wellhead, potable water of Yefrin from Rumia wellhead, potable water of Benghazi from Zayana wellhead and potable water of Ghadames from Faras wellhead.

In addition to that, some wellheads have been exploited in providing water needs for agrarian purposes, such as the wellhead of Taorga, which is located in the south east of Misurata with yearly productivity of 60 million cubic metres.

5.1.1.4 Dams

As mentioned earlier, the average annual rainfall is 26 millimetres total mean annual runoff calculated or measured at the entrance of the Wadis in the plains (or spreading zones) is roughly estimated at 200 million cubic meters /year, but a large part of it evaporates or recharges the underlying aquifers. Therefore, the regular renewable surface water sources are estimated at 100 million cubic metres /year. Currently there are 16 dams in operation with a crest higher than 10 metres. No new dams are under construction, but rehabilitation of the wadi Qattare main dam and reconstruction of the secondary dam have just been started. A number of new dams are planned, but construction has not yet begun as a result of financial constraints. The total storage capacity of these dams is 385 million cubic metres with an average annual storage capacity of about 61 million cubic metres (table 5.4).

The total average annual design storage does not necessarily correspond to an additional water source .As an example, the actual flow records (1982-1999) of Wadi Ghan indicate an average storage of only 3.99 million cubic metres /year, as opposed to the design figure of 11 million cubic metres/year. Moreover, certain dams have been damaged and are not in a position to store the amount of water they were designed for (Wadi Qattara). It is estimated that the real average water source made up by the existing dams does not exceed 30 to 40 million cubic metres /year (tables (5.4) and (5.5)).

Table (5.4): Dams in Libya

Dams	Reservoir Capacity (106 Cubic Metres)	Average Annual Design Storage(106 Cubic Metres/Year)
Wadi Maejenin	58	10
Wadi kaam	111	13
Wadi Ghan	30	11
Wadi Zaret	8.6	4.5
Wadi lebda	5.2	3.4
Wadi Gattara	135	12
Murkus	0.15	0.15
Bin Jawad	0.34	0.34
Zaza	2	0.8
Abu Mansur	22.3	2
Wadi Tabrit	1.6	0.5
Wadi Dakar	1.6	0.5
Wadi Jarif	2.4	0.3
Wadi Zahawuiyah	2.8	0.7
Wadi Zabid	2.6	0.5
Derna	1.15	1
Total	384.74	60.69

Data sources: International Small Hydro Atlas. (http://www.small-hydro.com).
Saad.A.Algghariani. 1993. Satisfying Future Water Demand Water of Northern Libya.
Salem, O.M.1992. The Great Manmade River Project. in: Water Sources Development, 8(4).

Table (5.5): Constructed Dams and Existing Capacities

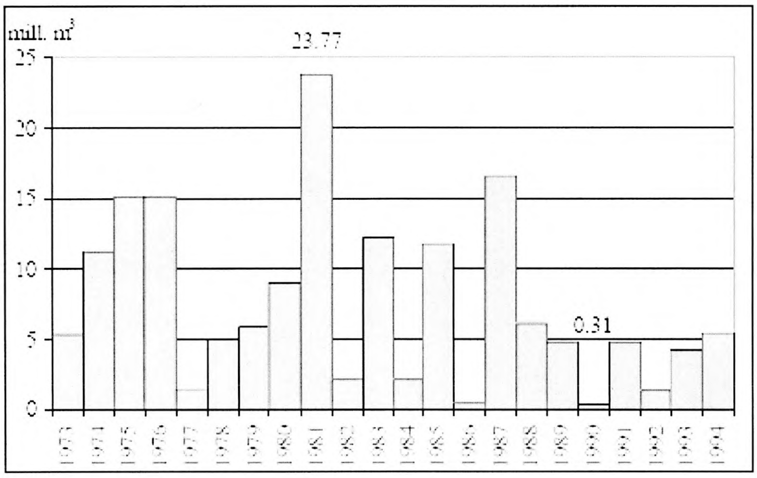
Region	Dam Name	Location	Storage Capacity Million Cubic Metres (Designed)	Existing Storage Million Cubic Metres/ Year
Jabal al-Akhdar	Wadi Garara Mrks Zara Dena Abomansour	Benghazi Ras-hlal Aloqurea Derna Derna	135 0.15 2 1.15 22.3	12 0.15 0.8 1 2
Kufra/as-Sarir	Garif Zhawia Ziud Benjuid	Sirt Sirt Sirt Benjuid	2.40 2.80 2.60 0.34	0.3 0.7 0.5 0.3
Gefarah Plain	Wadi Mejnean Wadi Ghan Wadi Zart	Ben-Gashir North Geran Rabta	58 30 8.60	10 11 4.5
Nafusah/al-Hamada	Wadi Ekaamm Wadi libda Wadi Tibreat Wadi Edkaar	Zliten Homes Zliten Zliten	111 5.2 1.6 1.6	13 3.4 0.5 0.5
Total Storage Capacity (Million Cubic Meters)			384.74	60.65

Data sources: Edawi. W and Ronny .V.2007. An Alternative Solution of the Water Shortage Problem in Libya. Water Resource Manage. (21): pp. 961-982

The construction of dams on two large rivers in north east and the north-west, Wadi Megenin and Wadi Gattara the towns of Tripoli and Benghazi are protected from floods, which caused important damage before the construction of the dams. As mentioned before sixteen dams were carried out, primarily for this purpose. In fact five of them only have relatively important volumes of storage to fill the objective of protection against floods (those of storage capacity between 22.3 and 135 million cubic metres), the remainder have storage capacity between 0.34 and 8.6 million cubic metres. Desertification is an important problem due firstly to water sources decreasing, caused by overexploitation of the water sheet, and secondly, to the deterioration of water quality of the water sheets, especially those located in coastal zone, salt water intrusion seasonal changes of precipitation affect supply of surface runoff through the effects on the precipitation efficiency which depends mainly on temperature and evaporation. Deficient precipitation is reflected by an absence of permanent rivers or streams in Libya. The total mean annual runoff in the dry wadis in the northern parts of Libya is controlled by annual precipitation. For example, El-Majenin Lake does not store constant water every year from precipitation. Part of it either evaporates or contributes to recharge groundwater aquifers.

It can be deduced that the amount of surface water in Libya varies sharply due to precipitation. In humid years, a large amount of water can be stored and, vice-versa. For example, in 1981, the amount of reserved water in El-Majenin lake was 23.77 million cubic metres while 1990 was the lowest (0.31 million cubic metres) from 1973-1994 (Figure 5.2).

Figure (5.2): Inter-Annual Variability of Reservoirs Water in El-Majenin Lake, 1973-1994



Data source: EL-Sherief, S. (1995): Water Amount Reserved in the Al-Majenin Dam Lake (1973-1994), Unpublished Report, General Water Authority, Tripoli, Libya

Water sources in Jifara Plain consist of surface runoff and groundwater; surface runoff water reaches the plain through many wadis from the annual precipitation over Jifara Plain and Jebal Naffusah, the length of wadis does usually not exceed a few kilometers. Thirty two wadis have a catchment basin larger than 30 square kilometres and only eight of these have a basin ranging from 300-700 square kilometres, for example the total catchment area of Al Hirah wadi is 80 square kilometres and average total runoff along the foot of the Jebal Naffusah escarpment is 87.2 million cubic metres/year (Pallas, 1980: 566). Only a few wadis can reach the sea. Surface water reservoirs have been constructed in the wadis by constructing dams in Jebal Naffusah to protect cities from floods and soil from erosion. The greatest part of surface water in these wadis infiltrates into the wadis beds or evaporates. The annual aquifer recharge by surface runoff dispersal and wadi bed infiltration is estimated to be not more than 800 million cubic metres (Kruseman and Floegel, 1988: 775).

5.1.2 Underground Water

Groundwater in Libya is the main source of water supply in 2005 with 87% of the water needs and 13% for other sources (table 5.1). In addition it is found in five basins, three of them in northern Libya: Jifara Plain, El Jebal El-Akhdar, El-Hamada El-Hamra, two in southern Libya: Murzuq and El-Kufra-Serir. The basins in the north suffer from severe deterioration; their recharges have not been precisely determined, it is estimated about 500 million cubic meters per year only from precipitation. Water storage of the basins in the south is not renewable, but the basins contain huge storage of fossil water. These storages are transferred to the northern areas by the Great Man-Made River Project (Eltantawi, 1998a)

Rock layers these are originally rainwater falling in certain areas, leaking partially into the underground through rock ground cracks and settling finally there. Groundwater could be renewable (in case of direct or indirect water feeding like, for example, the feeding of underground reservoir beds of Kufra and Sarir). In such cases, waters are held back in geological structures as a result of partial leaking of rainwater to them since thousands of years. They became deep and isolated from the feeding area.

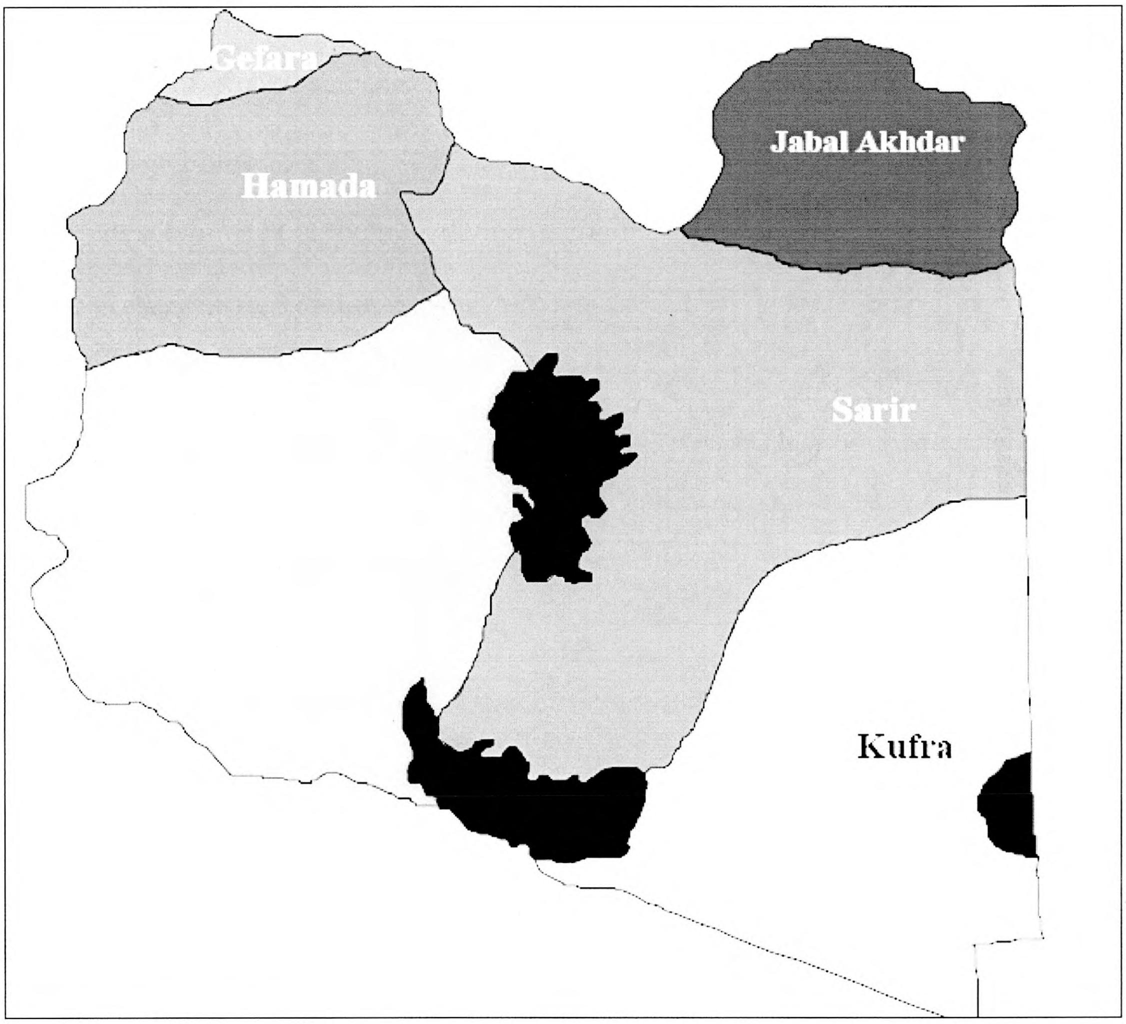
In addition, underground water is of great importance as a suitable source of meeting the human consumption of water. Most of the significant groundwater sources of North Africa are located in the southern Saharan and Sub-Saharan regions far away from dense population centers and important socio-economic activities. This situation posed the question of whether to move people and their socio-economic activities to where groundwater can be explored and economically exploited or to pump water and mass transfer it to where it is most urgently needed. Thus, Libya has emphasized huge mass water transfer schemes through its Great Man-Made River project (Algheriani 1997),

In the past, groundwater was easily extracted through large-diameter wells, dug using traditional tools, since water levels were very near to the surface. However, starting from the early sixties and coinciding with the oil boom, groundwater extraction rates accelerated rapidly and the use of centrifugal and submersible pumps became necessary to cope with the falling water table.

The regions of groundwater in Libya are divided into five water reservoir beds (table 5.3) as follows:

1. Reservoir Bed of the Level Land of Jifara.
2. Reservoir Bed of the Al Jabal Alakhder.
3. Reservoir Bed of Hamada Elhamra.
4. Reservoir Bed of Murzuk.
5. Reservoir Bed of Kufra/Sarir.

Figure (5.3): Groundwater Basins



Data sources: Salem, O.M 2007. Water Resources Management in Libya

Groundwater sources are divided into two major categories as shown in table (5.6) and figure (5.4): renewable and non-renewable. The renewable groundwaters are those retained in the northern aquifers of the Jifara plain, Jabal Akhdar and parts of the Hamada and central zone area. The non-renewable groundwaters are those belonging to the great sedimentary basins of the Kufra, Murzuk, Sarir and the Hamada. These basins underlie the southern part of the country, which has severely arid conditions. Rare events of heavy showers producing local runoff do take place, especially in the Haruj mountains in the centre of the country, in the Tibesti mountains in the south and in the Aweinat mountains in the west. These events may cause local recharge, but it is of minor importance in comparison with total storage values and aquifer losses.

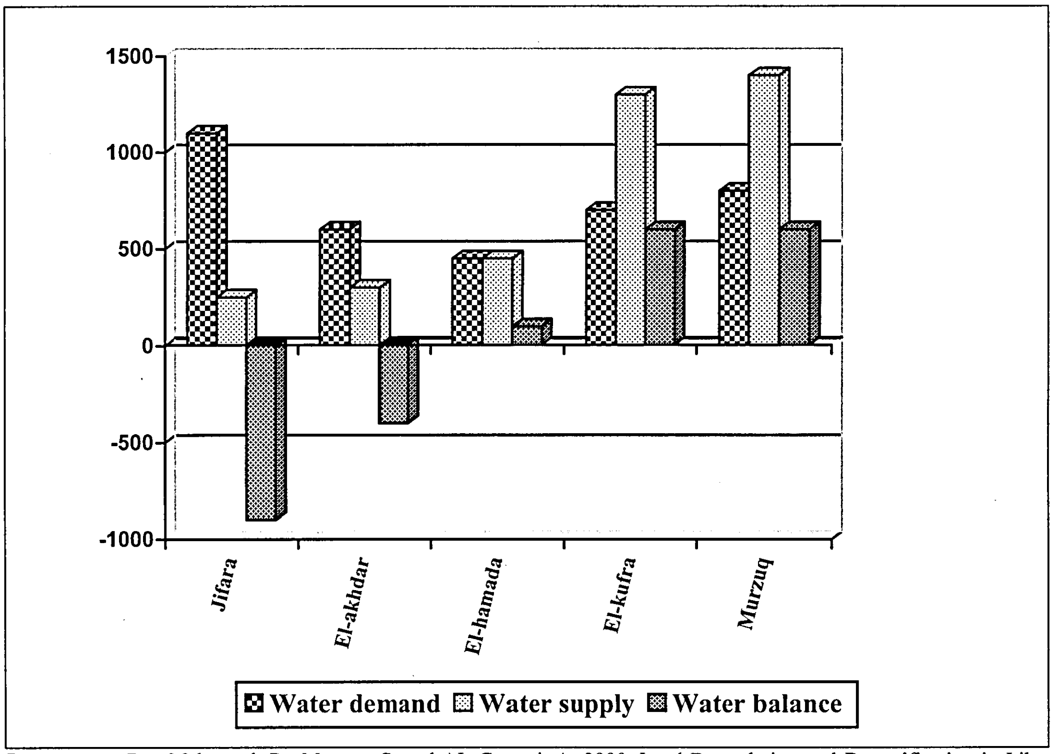
In the following a general idea is given about groundwater of each water reservoir bed:

Table (5.6): Groundwater Reservoir Characteristics

Basin Characteristics	**Area, (Square Kilo Metre)**	**Renewable, Million Cubic Metres**	**Non-Renewable Million Cubic Metres**	**Total Dissolved Solids, mg/1**
Jabal al-Akhdar	145,000	200	50	1,000-5,000
Kufra/as-Sarir	700,000	-	1,800	200-1,500
Gefarah Plain	18,000	200	50	1,000-5,000
Nafusah/al-Hamada	215.000	250	150	1,000-5,000
Murzek	350,000	-	1,800	200-1,500

Data sources: Edawi. W and Ronny .V.2007. An Alternative Solution of the Water Shortage Problem in Libya. Water Resource Manage. (21): pp.961-982

Figure (5.4): Water Balance in the Ground Water Basins in Libya 2000 (Million Cubic Metres)



Data source: Ben-Mahmoud, R., Mansur, S. and AL-Gomati, A. 2000. Land Degradation and Desertification in Libya, Land Degradation and Desertification Research Unit. Libyan Centre for Remote Sensing and Space Science. Tripoli, Libya

There are two basins located in the north of Libya, and it considered renewable water as Al-jabal Al-Akhdar (200 million cubic metres with a taking away of 600 million cubic metres) and AlJifarah (200 million cubic metres with an annual taking away of 1200 million cubic metres). However, there are more than two basins containing important water potential, but it considered non renewable water such as (Murzuk, Sarir,and Kufra) the Al-jabal Al-Akhdar Mountainous area in the eastern corner. This is the most important agricultural location and the majority of Libya's population is concentrated along the Mediterranean coast. This region is influenced mainly by the Mediterranean Sea climate as mild winter and not excessively hot but dry summers with high humidity and substantial rainfall.

Nearly 35% of the sheets have salinity higher than 5g/1; this salinity is due in the coastal zones, with the sea water intrusion caused by overexploitation (Jifarah and Jabal Lakhdar)

The renewable ground water is estimated at 800-1000 cubic metres/year but a significant part of this potential, perhaps 50%, cannot be extracted without a major risk for the environment (FAO 1997).

Libya is subdivided into five water zones, representing the major groundwater basins or aquifer systems. It is therefore necessary to define the water balance for each basin separately. The uneven distribution of population and the intensive agricultural activities in the coastal plains make the gap between supply and demand much wider in the Jifara and Jabal Akhdar plains. Table (5.7) summarizes the water balance for each basin.

The imbalance between supply and demand is expected to grow much wider in the future, especially for the northern basins. The immediate remedies already considered include interbrain water transfer, desalination and wastewater treatment. Other complementary solutions cover legislative measures, charges and public awareness.

According to water balance of the groundwater basins in Libya, a severe deficit in water supply occurs in the Jifara Plain basin and moderate deficit in Jebal El-Akhdar basin explained by concentration of population in northwestern and northeastern Libya. While there is no deficit water in the southern basins (El-Kufra-Serir and Murzuq), this water is not renewable figure (5.4). Groundwater in southern Libya is from last pluvial period to Ca. 8000 years. UN research groups estimate the amount of groundwater in El-Kufra basin with 200 billion cubic meters and in Sarir 15 billion cubic meters (Schliephake, 2004: 210).

Table (5.7) presents the groundwater abstraction per area during the period 1975-2000. The total abstraction of 4 200 million cubic metres/year is about 8 times the annual renewable groundwater sources and therefore Libya depends heavily on fossil groundwater. The coastal aquifers are the only ones that are being recharged by rainfall, but uncontrolled groundwater development from these aquifers exceeds the annual replenishment. This has caused a severe water level decline and seawater encroachment, which makes the coastal groundwater sources almost unusable because of their high salinity of the total water withdrawal of 4 268 million cubic metres in 2000 (table (5.7)), about 82%, is used for agricultural purposes, 8% for domestic use and 10% for industrial use.

Table (5.7): Total Ground Water Withdrawal in Libya from 1975-2000

	Water Abstraction in Million Cubic Metres/Year					
Area	1975	1980	1985	1990	1995	2000
Aljabal al Akhdar	134	205	255	339	290	334
AlKufra-As sarir	224	295	487	526	560	575
Jifara	567	600	780	860	1070	1060
Hamada el Hamra	132	299	418	431	417	405
Murzuk	430	1055	1181	1306	1519	1754
Jabal Hasawna	0	0	0	0	0	140
Total	1487	2454	3120	3462	2855	4268

Data source*:* Pelles, p 2002 Water Sources of the Socialist People's Libyan Arab Jamahiriya in the Geology of Libya. Proceedings of the Second Symposium on the Geology of Libya. Academic Press London.

A high evaporation rate reaching up to 100% is an additional challenge facing water sources in arid and semi-arid lands. A combination of salt water intrusion due to sea level rise and increased soil salinity due to increased evaporation are expected to reduce the quality of shallow groundwater supply, excessive demand already contributes to saline intrusion problems in many parts in northern Libya. The water deficit has been aggravated by water level declines and quality deterioration especially around agricultural lands and urban areas where excessive using of groundwater gave way to seawater intrusion. Water level declines at more than 1 m/year and total dissolved solids exceeded 9,000 milligram/ liter over the last four decades (Abufayed and EL-ghuel, 2001: 49). As a result of sea level rise, some water supplies have become unusable due to the penetration of salt water into coastal aquifers (Jifara Plain, Sirt, Jebal El-Akhdar). Thus, monitoring, analyzing and forecasting variation of climate are of prime importance particularly for policy- and decision makers (Mgely, 1984: 3). Changing temperature and precipitation regimes cause changes in the water budget. As a result, irrigation and flood control systems, water storage, and hydroelectric installations as well as for a production systems are seriously affected.

5.1.2.1 Renewable Underground Water Sources

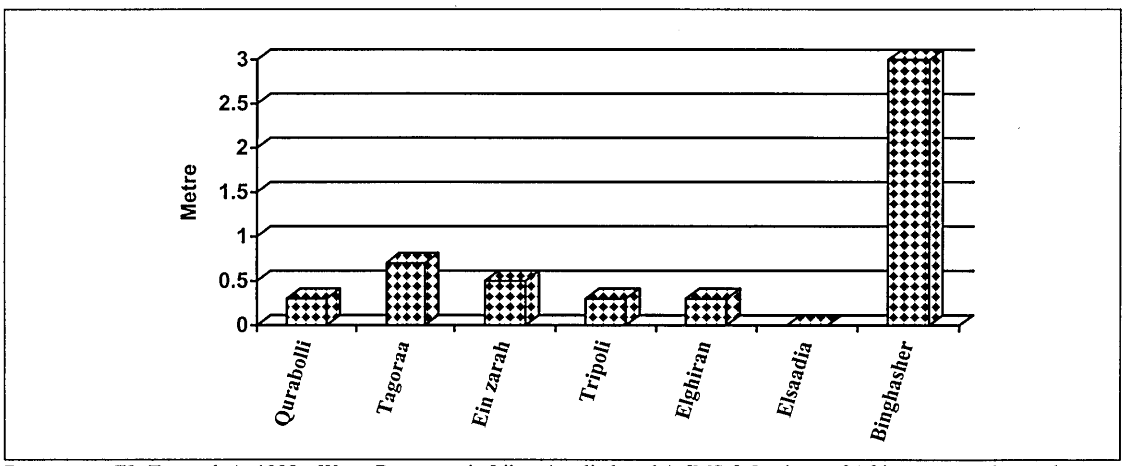
A- Reservoir Bed of the Level Land of Jifara

The reservoir bed of the level land of Jifara is located in the north west of Libya and surrounded by Naffusa chain of mountains, the Mediterranean Sea and the Libyan-Tunisian frontier. The level land of Jifara includes the cities of Tripoli, Zawia and Subrata. It has a population of more than half of the total population of the country, i.e., in fact, over 50% of the total population live in the Jifara plain and Jabal Nafusa, making the population density over 120/km^2. In the central and southern parts of the country, the population density is below 1 /km^2. Jifara Plain suffers from severe hydrological drought; water behind dams experienced to be decreasing or disappearing (General Environment Authority, 2002: 206) resulting from erratic and great variabilities of precipitation. Benefited precipitation in Jifara Plain is only 15-20%, while lost water is 70-78% through evaporation, 2% waste to the sea and 5% infiltrate into the soil (Ksoudh, 1996: 329). In addition, high temporal and spatial variabilities of precipitation lead to a greater variability of short duration runoff, accelerated soil erosion by water and high sediment transport rates. Water scarcity seriously affects pastoral and agriculture activities in Jifara plain. Water balance, computed by Thorn Waite at three stations clarifies a big gap between precipitation and evaporation. It can be noticed that water deficit prevails for nine, eight and nine months per year at Al-Azizia, Tripoli city and Zuara, respectively. It can also be seen that during summer, spring and autumn, water demand is greater than water supplied though precipitation. As a result, vegetation suffers from deficiency of water, as well as soil moisture and accelerates water scarcity. Groundwater is the major source of water in Jifara Plain. The upper aquifer (Miocene-Pliocene-Pleistocene) collects water under unconfined conditions and extends throughout the Plain; it is 100-150 m thick and contains good quality water in the central and eastern parts, the middle Miocene aquifer is well developed in the western part of the Plain and found at 70-120 m below the surface with thickness of the aquifer between 125-200 m.

Clay layers separate the aquifer from the quaternary and lower Miocene aquifers (Sadeg, and Karahanolu, 2001: 1155). Ground water is mainly recharged from precipitation, infiltration from surface runoff which inflows from the south.

The scarcity of water was aggravated by water level declines and quality deterioration. Water level declines over 1 m/year in some parts (figure (5.5)) and total dissolved solids have exceeded 9,000 mg/liter in the last four decades (Abu fayed and El-Ghuel, 2001: 49). Water levels have dropped in most parts and, along the southern boundary, draw down of more than 30 meter is recorded. In addition, water levels often drop below sea level, presumably because of excessive discharge from a well field located in this area (Sadeg, and Karahanolu, 2001: 1161). In 1968, ground water level decreased 1 m in some areas around Tripoli and it experienced sea water intrusion (BAQI, 1991: 119).

Figure (5.5): Annual Decrease of Groundwater in Different Parts of Jifara Plain



Data source EL-Tantawl, A. 1998a. Water Resources in Libya (applied study). [MSc]. Institute of African Researches and Studies. Cairo University (in Arabic).

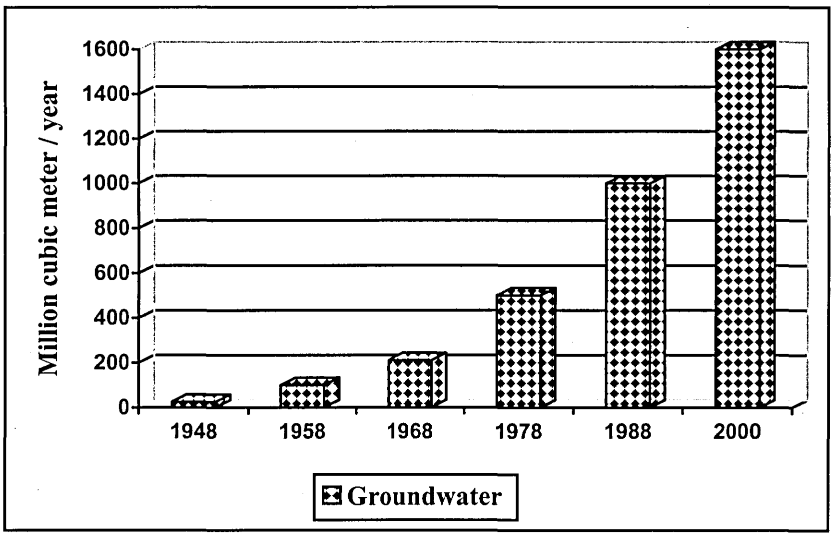
Over-extraction of groundwater in the coastal parts, particularly, in eastern Jifara Plain, has led to a continuous decline in the groundwater level and sea water intrusion which is estimated to be advancing at a rate of 100-250 m/year. If this over-extraction is not stopped or reversed, it is expected to deteriorate all productive aquifers in the near future (Ben-Mahmoud, et al., 2000). A serious deficiency was thus produced between the natural water supply and the quantities exploited; it is estimated, for instance, that over one billion cubic metres are annually taken from the reservoir of Jifara Plain, where farming activities use up a share equivalent to almost 80 % of the total consumption (National Committee to Combat Desertification, 1999). Water deficit in Jifara Plain was 1281.5 million cubic metres in 1998 or six times the sustainable none groundwater observation (General Environmental Authority, 2000: 63).

Underground water in some parts under consistently heavy drainage started to run dry and turn increasingly saline. This aquifer forms the major source for agricultural, domestic and industrial purposes for the Tripoli area. The seawater/freshwater interface would migrate landward leading to a very critical problem. (Sadeg, and Karahanolu, 2001: 1152).

Groundwater is subject to excessive mining as it is located in the most populous and intensively agricultural region of Libya and because of its ever-increasing water demand from underground water sources. The main groundwater use is for irrigation (in 1998 1,472.5 million cubic metres) and for other purposes: livestock (4.3 million cubic metres), urban use (188.1 million cubic metres) and industry (10.1 million cubic metres) (General Environmental Authority; 2000:60).

In recent years, the risk of seawater intrusion is continuously threatening coastal parts of the Plain that form one of the economically most significant areas in the country. High level of urbanization and increased agricultural and economic activities have required more water to be pumped from the aquifer (Figure 5.6). This pumping has continually increased the risk of seawater intrusion and deterioration of freshwater quality.

Figure (5.6): Groundwater Use in Jifara Plain 1948-2000



Data source: National Scientific Research Authority, , 1999: 39, EL-Reibi, 1998: 13, and General Environment Authority, 2000: 60

Table (5.8): Groundwater Quality in Some Parts of Jifara Plain

Well number	Site	Analysis Date	Melted Salt Parts, Parts per Million
70/24	Zura	24/5/1976	6,776
77/255	Zura	21/1/1979	24,740
80/171	Alesa	13/4/1981	10,000
76/272	Alesa	28/10/1999	7,236
87/82	Alakrabia	12/3/1989	6,000
87/83	Alakrabia	5/4/1989	5,800
87/84	Alakrabia	23/4/1989	6,000
77/72	Algamel	10/8/1977	2,191
77/73	Algamel	10/8/1977	6,056
77/74	Algamel	17/7/1977	4,100
76/284	Sebrata	12/7/1976	1,512
76/49	alogailat	13/4/1976	4,868

Data source: Intonation Center of Water, 1999

Groundwater is also subject to poor quality. In spite of the safe limit of total dissolved solids in water being 1500 ppm, it reached in Es-Sawani station 3,800 ppm and 23,000 ppm in Zamzam stations, sea water ranged between 36,000-37,000 ppm (Mgely, 1994: 154). This means that the pollution of groundwater in some parts in Jifara Plain ranges between 3 to 15 times the acceptable world standards (table (5.7)).

B- Reservoir Bed of the Al jabal Al akhder

The reservoir bed of the Al jabal Alakhder is located in the north east of Libya. The region of the reservoir bed of the Al jabal Alakhder includes the level land of Benghazi beside the Al jabal Alakhder. The underground water of the reservoir bed of the Al jabal Alakhder is fed by direct leakage of rainwater. Some parts of the reservoir bed of the Al jabal Alakhder are exposed to depletion, becoming salty and invaded by seawater, specially in the level land of Benghazi.

The studies indicate that rainfalls in the region of Al jabal Alakhder reach an average of 800 million cubic meters per annum distributed as follows (Mohamed Elsalawy ,1992):

- 250 million cubic metres for feeding the underground water of the reservoir bed of the Al jabal Alakhder.
- 80 million cubic metres of water flow into valleys.
- 150 million cubic metres of water evaporate in salt marshes.
- 320 million cubic metres of water go to waste (by flowing into the sea).

Non-renewable water, also known as "fossil water" generally consists of infiltration of very ancient water, in climatic and morphological conditions different from the present ones, which are therefore outside the contemporary water cycle.

C- Reservoir Bed of Hamada Elhamra

The reservoir bed of the Hamada Elhamra (also called reservoir bed of the middle region) is located east of the level land of Jifara, north of Fezzan and west of the eastern region of the country. It includes the area of the reservoir bed of Hamada Elhamra, Khums, Misurata, Taorga, Zletin, Suf Eljjeen and Sirte.

The reservoir bed of Hamada Elhamra is characterized by existing of many underground reservoir beds along the coastal strip.

Rainwater of the region is considered the main source for feeding the reservoir bed. The water of the reservoir bed of Hamada Elhamra varies from good to moderate to salty and it is hot in some areas.

5.1.2.2 Non Renewable Underground Water Sources

A- Reservoir Bed of Murzuk

The reservoir bed of Murzuk is located in the south west of the country. The lower reservoir contain high quality water with saltiness not exceeding 15 g/l. the studies run to determine the water age of this reservoir bed gave evidence, that the age is between 4000 and 14000 years. This means that it is very old water, which gathered thousands of years ago. And it is to be known, that there is no feeding[1] to the said reservoir. The exploitable water quantity of the reservoir bed of Murzuk is estimated to be about 1300 million cubic metres per annum. Therefore, it was decided to convey the water quantity exceeding the needs of the region to the North West regions of the country, which suffer under remarkable shortage of water. The water quantity to be conveyed is estimated to be about 790 million cubic meters annually (one of the phases of the great man-made river project) (General Environmental Authority, 2000: 60).

B- Reservoir Bed of Kufra/Sarir

The reservoir bed of Kufra/Sarir is situated in the south east of the country. There are huge quantities of high quality waters in this bed. Due to the fact, that there are inadequate precise data and information about water availability in the north of Sudan, north of Tchad and neighboring countries of this reservoir bed, no crucial answer could be obtained in regard of the feeding of the reservoir bed of Kufra/Sarir from those regions, if any. The exploitable water quantity in the region Kufra/Sarir is estimated to be about 2610 million cubic metres per annum

1 Feeding is in fact the ever renewed annual flow into the water reservoir bed.

for duration of approximately fifteen years against lowering of the water table by about 100 metres.

Due to the existence of a huge water quantity in the reservoir bed of Kufra/Sarir, it was decided to convey the water, which exceeds the needs of these regions, to the coastal strip, namely to the Al jabal Alakhder and the middle regions. The quantity of water, which will be conveyed, is estimated with 790 million cubic metres per annum (one of the phases of the Great Man-Made River Project). (Schliephake, 2004: 210

Water Resources Management

Water development projects were also established as part of national programs and activities to combat desertification. The main objectives of water management are reduction of the water deficit and improving water quality that can be achieved through: the rainfall harvest and control of runoff by constructing more dams on wadis to store runoff waters and prevents flood hazards (Ben-Mahmoud, et al., 2000).

Wadis are heavily settled because their soils are often very suitable for agriculture, and the high water table in their vicinity makes them logical locations for digging wells. Libya has paid attention to this problem and has diverted water development projects, particularly around Tripoli (The Library of Congress, 1987). Groundwater supplies must be kept in balance with the requirements of land use to face the sea water intrusion. Most of North Africa nations practice one or more water harvesting techniques intensively in order to collect and store rainwater for use in meeting plant demands as well as human and animal needs (Nasr, 1999: 29). Also alternate sources of irrigation water are applied such as treated sewage water. Desalination will thus play an ever-increasing role in the future of Libya's development, not only to ensure the continuous supply of water to existing communities and industries in particular, but also to allow the development of new ones as well. Moreover, desalination has a special strategic role as a readily available, alternative standby source in cases of partial or total failure of the existing water sources (Abufayed and El-ghuel, 2001: 52).

5.1.3 Great Man-Made River Project

In view of the fact that most population, farms and industries are concentrated along the coastal strip, and because the water sources available in the north of the country are inadequate to meet the needs of water for the purposes of agriculture, domestic and industrial uses, it was decided to convey water from the south, where water is available in large quantities.

Many studies about underground waters in the south (resulting from the fall of heavy rains there some thousands of years ago) were done in order to find out the best methods of exploiting them economically.

Water Quality:

In the beginning of the sixties, when oil drilling penetrated south inside the Libyan desert, a tremendous great storage of fresh underground water was discovered. The most important rock strata carrying water were formed in the geologic of time when the Mediterranean Sea water used to flow southerly till they reached the Tibisti Mountains. In addition, sea water level due to IC ages changed occasionally and this led to the formation of sedimentary rocks of different kinds. These geological activities resulted in the emergence of Nafusah Mountain and the Al- Akhder Mountain and the formation of the underground water aquifers. These aquifers are porous sedimentary rocks where water accumulates in it and are surrounded by non-porous rocks.

About 14,000 to 38,000 years ago, the climate of North Africa was mild. Libya used to have high rainfalls therefore, rainwater leaked inside the porous rocky strata and stored in it forming fresh underground water. There are five main reservoirs of underground water. These are Al-Kufra, Sirt, Murzuq, Al- Hamadah and Jifarah. The first three reservoirs collectively contain around 35,000 million cubic metres of water. These huge storage amounts of underground water will provide the coastal areas with great quantities of water.

The analysis of results issued by the Department of Water & Soil it was found out that the sort water of the Great Man-Made River has very high quality and conforms with the international standard specifications. It is suitable for all purposes of use such as drinking, irrigation and industrial use. It was found out, for example, that the saltiness of the reservoir bed of Murzuk is about 300 particles in one million, while it is in the reservoir of Kufra only one particle in one million.

The Great Man-Made River Project described as the 'eighth wonder of the world' is a massive project and large water development scheme (Figure, 5.7). It is considered the biggest project to combat desertification in Libya. With four-meter-diameter pipes and a length of about 4000 km aiming to divert part of the groundwater from the southern basins to the coastal areas where about 90% of Libya's population has settled The Great Man-Made River Project, which is designed to supply about 6 million cubic metres a day of water to the coastal region from aquifers under the desert, where a huge amount of fossil groundwater has been stored since the late Quaternary, to the North, where the water is urgently needed. Mainly for irrigation, which is linked to the implementation of the project but part use for the water, supply of the major cities. About 66 per cent of the water is for agricultural purposes. The Great Man-Made River water authority is responsible for finding foreign investors to develop strategic agricultural projects.

The Importance of the Great Man–Made River Project

As shown in Table (5.9) there is a huge surplus of underground fresh water south of Libya which still awaits utilization. This surplus amounts to about 90% (Annihum (1994)) of the underground storage for Al- Kufra reservoir, and 84% of the underground storage for Al-Kufra reservoir, and 84% of the surplus of Sarir reservoir stock can be used in compensating the severe shortage of waters in the coastal cities.

Table (5.9): Water Supply for Libya
(Million Cubic Metres Year)

Year	2000	2005
Underground Water	3430	3430
Surface Water	120	120
Desalinated Water	130	135
Treated Water	220	250
Total Supply	3900	3935

Data source: Al- Ghariani, S.A.1996. Integrated Water Management for Sustainable Development, Conference on Water Resource of the Arab World, Faculty of Agriculture. Al-Fateh University. Tripoli- Libya. (In Arabic).

Other alternatives were studied and discussed in the method of dealing with underground water in the two areas of Al-Kuafra and Sarir which are thousands of kilometres away from the inhabited areas. The first approach was to establish agricultural assemblages in Al-Kufara areas where water sites are found and irrigation assemblages through digging wells.

However, this was prevented by the poor soil in the southern desert areas and the difficulty of transferring the agricultural products to consumption areas especially vegetables and fruits which spoil in a short time in addition to the lack of sufficient manpower to cultivate the desert land. The alternative of transporting humans from increasing demand for water sites in coastal areas to underground reservoirs sites in the middle of the desert was suggested however, the idea did not receive any response nor approval by coastal cities inhabitants who kept living in these cities for long times. In addition, it was not accepted because many oil industries, which the Libyan Arab Jamahiriya depends on, exist near the northern coastal cities.

The studies concluded on the necessity of transferring the underground water from the south to the coastal consumption areas in the north. This was supported by the economical feasibility studies whish proved that the cost of extracting a cubic meter of underground water from Al-Kufara and Sirer reservoir and transport it to the costal cities through a concrete pipeline under the earth surface does not exceed 100 Durham (0.35$) compared to 1.271 Durham(3.75$) which is the cost of desalinisation of cubic meter of salt water and 950 Durhame (2.80$) which is the cost for transferring a cubic meter of water by marine carriers from the neighbouring countries to the Libyan Arab Jamahiriya.

Objectives of the Great Man-Made River Project

The project aspires through the agricultural investment programs to achieve the following objectives: Al-Rabty (1996)

- Achieving food security and increasing self-efficiency of different strategic commodities.
- Increasing the contribution of agriculture sector in the total local product, and expanding production base, increasing income and providing alternative source for oil in the national income.
- Achieving the social development in the targeted areas by investing through increasing income and providing work opportunities and stability.
- Maintaining the environment and natural sources protection in the investment areas by soil and vegetation cover conservation programs and growing windbreaks and establishing check dams to preventing soil erosion.

Stages of the Project

The Great Man-Made River Project is a civil engineering project and it is considered a new conquest of desert secret areas in order to utilize what it has underneath of fresh water sources. This is represented through extending an enormous system to transfer water from the desert to the fertile coastal areas through huge buried pipes at approximately a depth of 7 meters with an interior diameter of 4 metres when completing all its stages its length will be approximately 4,000 km., which forms an enormous artificial irrigation network. This project will be executed through the following systems, (figure 5.7)

Phases of the Great Man-Made Project.

- Aarir-Sirt/Tazerbo-Benghazi System.
- Al-Hasawinah- Al- Jifara plain System
- Connection link of Al-Gardabia-Assidada.
- Al-Jaghbub-Tubruq System.
- Al-Kufra-Sarir System.
- Ghadamis- Zuwarah- Azzawiyah system.

Water Transferring System (Sarir-Sirt/Tazerbo-Benghazi)

The system (Sarir-Sirt/Tazerbo-Benghazi) of the Great Man-Made River Project consists of two parallel lines of pipes, each of 4 metres in diameter. The first line is Sarir and the second is Tazerbo- Benghazi. The system transports 2 million cubic metres of water daily from the 2 well fields in Sarir and Tazerbo to balance reservoir in Ajdabiya with a 600 kilometres length of wells field of Tazerbo. The system is divided beyond Ajdabiya reservoir to two branches, one of which goes westward to transport water to locations extending from Ajdabiya to Sirt by water allocated 287 million cubic metres annually, of which 228 million cubic metres are allocated to agriculture, water utilization and agricultural development Utilization and Agriculture Development (1997). The other branch goes northwards in the direction of Benghazi to the final reservoir near the village of Suluq the water sources of this branch are 413 million cubic metres annually, which about 275 million cubic metres are allocated to agriculture water utilization and agricultural development Utilization and Agriculture Development (1998) table (5.10)

Table (5.10): The Allocation of Water in the Sarir-Sirt/Tazerbo- Benghazi) System for the Great Man–Made River Project

Data	Quantity of Water (Million Cubic Metres/Year)	
	Ajdabiya-Sirt	Ajdabiya- Benghazi
Total Flow	287.00	413.000
Total Loss in Pipelines and Reservoir	8.036	11.564
Civil and Industrial	50.340	126.884
Agriculture	228.624	274.552

Data source: Great Man- Made River. 1997. Water Utilization and Agricultural Development Master Plan Updating .Part II. Ajdadiya-Sirt System (in Arabic).
Great Man- Made River .1998. Water Utilization and Agricultural Development Master Plan updating .Part I. Ajdadiya-Sirt System(in Arabic).

Sarir and Tazerbo Well's fields

There are enormous stored quantities of fresh water in the desert in underground aquifers. These waters are being pumped to the ground level through wells their depth reaches to up 450 metres. These wells lie in both areas of Tazerbo and Sarir. Tazerbo well filed is composed of 108 productive wells whose waters gather in water collecting pipelines in order into pour into a reservoir at Tazerbo whose capacity is 170,000 cubic metres. From this reservoir, water flows naturally under gravity for a distance of 667 km through pipelines whose diameter is 4 metres to Ajdaebiy reservoir.

Sarir wells field is composed of 126 productive wells whose waters accumulate in water collecting pipelines in order to pour into two reservoirs at Sarir. The capacity of each is 170,000 cubic metres.

Ajdabiya balancing reservoir

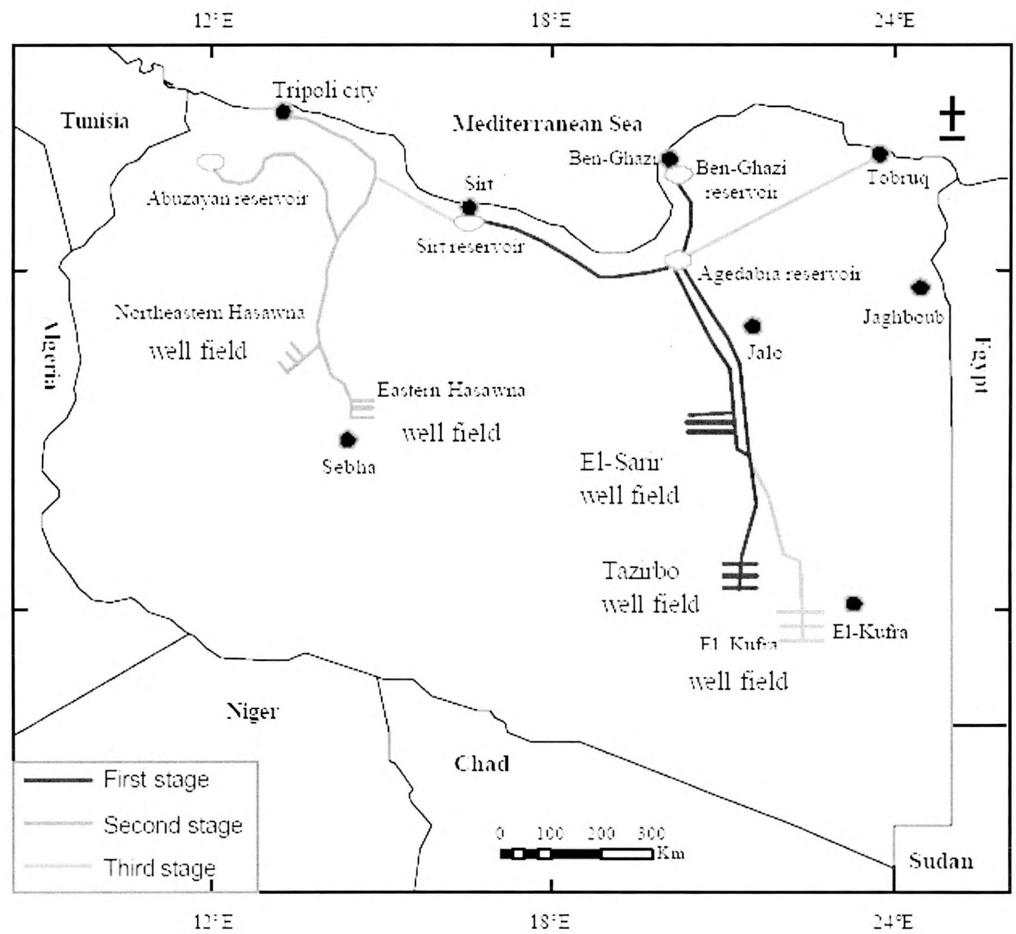
Waters flow from Sarir and Tazerbo naturally through two pipelines whose diameters are 4 metres for a distance of 381 km from Sarir and 667 km from

Tazerbo till Ajdabiya reservoir is considered as the assembling and storage point through which Waich water can be distributed to any of the two main branches.

Sirt and Benghazi Terminal and Agricultural Reservoir

Water flows naturally from the balancing reservoir at Ajdabiya with a rate of 820.000 cubic metres daily to Sirt terminal reservoir and with a rate of 1,180,000 cubic metres daily to Benghazi and reservoir. The capacity of Sirt terminal reservoir amounts to 6.8 million cubic metres and Sirt agricultural reservoir 15.4 million cubic metres. The capacity of Benghazi terminal reservoir is 4.7 million cubic metres and Benghazi agricultural reservoir 24 million cubic meters.

Figure (5.7): The Great Man-Made River Project in Libya



Data source: The Great Man Made River Water Utilization Authority, 1996: 13

Locations for Agricultural Investment

They were defined in the system of transporting water (Sarir- Sirt/ Tazerbo-Benghazi) for the Great Man-Made River Project so that they achieve the general strategy of agricultural development in the Libyan Arab Jamahiriya through the following pattern Water Utilization and Agriculture Development (1997), Water Utilization and Agriculture Development (1998) and Brown and Root (1988).

1-Supporting the existing farms with irrigation water in the following locations

A-locations pertaining to the (Ajdabiya-sirt) system

- Western wadis (Tilal,Jaref, Gebeba).
- Swawah and abou Zahia.
- Sultan and Al-Amillimetresara.
- Wadi harawa.
- Wadi Al-Henawa.
- Eastern Wadis (Kehila, Matratin,Mas'ouda and Al-Shadg).

B-locations pertaining to the (Ajdabiya-Benghazi) system

- Ghut sultan.
- Arrajmah project.
- Benghazi plain.
- Annawwaqiyah.

2-Reclaiming new areas and providing them with permanent irrigation system as general projects or settlement projects. These areas can be classified into three sections

A-limited projects specified either to serve some societies based on industrial project, or to support agricultural settlement projects. The pattern of small (settlement) farms were ratified for these for these projects:

Birhr project: which aims at covering the agricultural needs of Al- Brayqah Company for oil and petrochemicals.

Annuwfaliyah project: which aims at covering the agricultural needs of the of the Ras Lanuf Company for petrochemicals.

Benghazi project for small farms.

Wadi Tamit and Zukir projects to support agriculture settlements in these areas

B-Projects for Public Usage

Al Wadi Al-Ahmar pastures project

Growing Palms project in al- Wadi Al-Farigh.

Large project that aim at achieving the general policy of the Libyan Arab Jamahiriya in the field of agricultural production. These projects lie in the following areas:

Al-Gardabia. Al-Khadra area.

The Al-Khdra west.

The trends were remarkably contradictory since the beginning of investing the Great Man–Made River water until now about the investment pattern targeted in those large projects. The original trend was towards large farms pattern (public productive projects), but popular authorities interfered later and recommended small farms pattern, than the recent trend was to limit the small farms pattern to location with necessary infrastructure. Except for this, investment is directed towards large farm pattern in these projects.

Ajdabita-Sirt System

Total water allocation for the Ajdabiya- Sirt system are about 287 million cubic metres annually, with a daily flow that reaches 820.00 cubic metres for 350 days. The system stops working for 15 days for regular maintenance WUAD (1997), and Brown and Root (1988).

Agricultural allocations for this system are about 228 million cubic metres, or 80% of the whole allocations. These allocations suffice to irrigate an area of 25,000 hectares the rest is allocation to urbanization purposes Wuad (1997), and Brown and Root (1988)

Recommended Locations for Agricultural Investment

Done on the regions overlooking the Ajdabiya-Sirt system, the locations targeted for agricultural investment were marked in the most suitable soil so that it lies near large communities (Sirt). The investment philosophy focused on two principal criteria: First/ supporting some existing projects with irrigation water.

Secondly/ reclaiming new areas and subjugaing them to permanent irrigation as public productive projects (large farms) or as settlement small farms.

Small Farms Pattern (a settlement project)

The total number of small farms targeted for this system is about 4,200 farms. This pattern will be applied in Swawah, Abou Zahia, Bishr,, Annuwfaliyah, eastern Wadis(Kehila, Matratin, Mas'ouda and Al-Shadg), wadi al-ahmar, wadi harawa, sultan, al-ammara, wadi al-henawa, western Wadis (Tilal, Jaref, and Gebeba), Wadi Tamit and Zukir. The irrigation area for each farm ranges between 5-6 hectare. The already existing small farms had 6 hectares as net irrigation area. As for new small farms in the investment region, the net irrigation area inside each farm was 5 hectares

Large Farms Pattern (a production project)

Agricultural projects have been made and designed on the basis of large units of irrigation, each unit is called a large farm and its area varies according to irrigation equipment. The total area of the pattern of large productive farms targeted for this system is about 5,500 hectares. It is applied in Al-Gardabia and Al –Wadi Al-Farigh.

Ajdabiya-Benghazi System

The total water allocation for Ajdabiya-Benghazi system is about 413 million cubic metres annually, with a daily flow that reaches 1,180,000 million cubic metres for 350 days. The system stops working for 15 days for maintenance (Wuad, 1998; Brown and Root, 1988).

Agricultural allocation for this system is about 275 million cubic metres, or 70% of the whole allocation. It suffices to irrigate an area of around 40,000 hectares. The rest is allocated for urbanization purposes (Wuad 1998; Brown and Root ,1988).

Recommended Location for Agricultural Investment

As mentioned in the Ajdabiya-Benghazi System, the targeted locations were determined in the most adequate soil from the technical and economic studies (Moumen et al. 1989; Wuad ,1998; Brown and Root ,1988).

Done on the location the Ajdabiya- Benghazi system, so that they lie near to large communities (Benghazi). The investment philosophy focused on two principal criteria:

First/ supporting some already existing projects with irrigation water. Secondly/ reclaiming new regions and subjugating them to a permanent irrigation system as public productive project (large farms) or as small settlement farms.

Small Farms Pattern (a settlement project)

The total number of small farms targeted on this system is estimated to be about 3,200 farms. This pattern will be applied in northeast Al-Khadera, Ghut Sultan, Wadi al-Qattara, Benghazi plain and Annawwaqiyah. The total area of the small farm ranges between 7-12 hectares, of which 6 hectares represent the net irrigated area.

Infrastructure Works Required for These Projects Include

Establishing water distribution networks.

Establishing electricity distribution networks.

Constructing networks of internal roads between farms.

Constructing water reservoirs in each farm, with a 240 cubic metres capacity.

Constructing windbreaks and enclosures around each farm.

Constructing networks of drainage to protect farms against floods.

Large Farms Pattern (productive project)

This pattern cares about constructing agricultural project designed on the basis of large units of irrigation; each is called a large farm and its area varies according to the type of irrigation equipment used. The whole area of the large farms pattern (the productive ones targeted on this system) is about 11,300 hectares.

This pattern is applied in the Northeast Al-Khadra, Al- Khadra West and Ghut Sultan networks, networks of electricity, road networks and constructing large irrigation equipment.

Crop Pattern for Investment Projects

Targeted crops were chosen either in small farms or in large farms, based on making an adequate crop pattern that can achieve a good economic result from using the great man-made river water, and can match the general food strategy of the Libyan Arab Jamahiriya on the basis of achieving a high rate of self sufficiency in agricultural production, especially in grains and fodder. Moreover, it puts into consideration simplifying the necessary agriculture action, especially in small farms.

There was a focus in the proposed crop pattern on the field crops to produce grain necessary to cover the food needs of sheep, besides guaranteeing local marketing of them when there is a surplus. A limited area was allocated to the production of fruits and vegetables inside every small farm to cover the needs of families besides the ability to provide extra income for every family when these crops are locally marketed.

These crops were chosen for investment projects on the Ajdabiya-Sirt system and the Ajdabiya–Benghazi system for the following technical reasons:

1-Barley: It is an essential crop in small farms because it is the traditional winter grain for all farmers, and it is the most acclimatizing of all crops. It is also a source of energy for sheep.

2- Wheat: a strategic crop targeted in the general plan of the Libyan Arab Jamahiriya to achieve food security through achieving self- sufficiency of it. Therefore, it is the principal grain in these crops.

3-Alfalfa: It is a highly productive fodder. It prevails a high quantity of protein and energy to livestock throughout the whole year. It is also of great economic value in the local market, which makes good income for the farmer when he sells the surplus. It is also a permanent crop that lasts more than 3 years in the soil and forms a strong basis for a new agricultural cycle that guarantees improving the soil qualities and its degree of fertility, hence improving its productive power.

4-Corn and oat mixture: they are considered seasonal fodder when the growth of alfalfa is slow, the chick ling Vetch and Oat mixture play that role in winter, while Sorghum or Corn play that role in summer. Oat mixture and Sorghum may not be familiar to a farmer, but they do not differ from other folders in the way they are cultivated, however they are cut while they green before they become.

5-Fruit trees and vegetables: crops of small farms included limited areas specified for producing vegetables and fruits that are most suitable to irrigation agriculture under the local and environmental conditions such as tomatoes, beans, marrows, okras, grapes, figs, pomegranates and olives. This area was specified for achieving self-sufficiency of these crops in the farm, besides being able to sell the surplus in the local market to achieve extra revenues for the farms.

5.2 NON-CONVENTIOAL WATER SOURCES

Since the mid-seventies many studies and researches have shown that there is evidence of a problem to come in regard to water shortages in the Libyan economy due to the inability of the usual water sources to face a long-term exploition of water. It became obvious that unusual complementary water sources have to be found urgently in order to provide needed water. Unusual water sources could be desalination of seawater or purification of sanitary drainage water.

Different non-conventional water sources are considered as potential water sources. These sources will be described follows:

Signs of water shortage began to appear in the early 1970s as a result of fast economic development. Studies have already predicted that demand for water will grow at an alarming rate which cannot be met from conventional sources alone. It was then decided to introduce desalination as a partial solution for domestic water supply.

Special attention was also given to distillation water or sewage treatment. Treated water is used for irrigating orchards, fodder and other indirectly consumed crops.

5.2.1 Desalination Water (Treatment of Seawater)

Desalination is the process of removing dissolved salts and other chemicals from seawater, brackish groundwater, or surface water. Depending on the desalination technology utilized and the desired level of treatment, the desalination process can be used to produce water suitable for potable (drinking/domestic uses) and non-potable uses (industry, irrigation. etc.).

The desalination plants project is considered as one of the important projects become it is the other choice for many Arab countries especially the Gulf States which use techniques of desalination plants for agriculture, domestic and industrial purposes.

Due to the water shortage in Libya, a National Committee has been formed to find the possible ways and recommendations to concentrate on the water desalination (Salem 1998).

Along the coastal strip there are 27 seawater desalination stations constructed in the regions, which suffer from water shortages. The desalination industries are considered to have a major role in developing human life. Recently this technology became widely distributed, and its contention along the coastal area has been widely reported. Many countries are adopting these technologies for securing fresh water supply for consumer consumption all over the world.

Desalination plants were first introduced to Libya on a small scale by petroleum companies in the 1960s. Now Libya depends on the desalination techniques to save water demands of many regions, due to the exhaust of groundwater in coastline and the high level of contamination.

The desalination technologies are considered to be very important as non-customary source of planning for fulfilling the Great Man-Made River Project to save the potable water demands, especially for the areas, which do not reach the great Man Made River project.

As shown in Table (5.12), desalination plants have been operating since 1975. Over this period the total installed capacity has grown to more then 330,000 cubic metres/day are produced by multi-stage flash (MSF) and the rest by multi-effect distillation (MED).

Desalination plants in Libya are almost dependent on thermal technology. There have been several attempts during the last 25 years to introduce and expand sea water desalination plants and wastewater treatment facilities. A number of desalination plants of different sizes have been built near large municipal centres and industrial complexes. However, so far restrictions have been imposed by the high cost of energy and spare parts. The contribution of the existing desalination plants is almost negligible and exclusively used for domestic and industrial purposes. The total capacity of installed plants is only about 18 million cubic metres / year, and 366,840 cubic metres /day. Libya is at the 7th rank of the countries with the largest seawater desalination plants (see Table 5.11).

Only 10 plants are in service. They have a capacity production of 262,500 cubic metres /day. Ten plants are now under repair. They have a production capacity of 135,400 cubic metres /day. The others are out of order and have to be renewal. Libya realize, or intend to realize 20 plants of sea water desalination for a capacity of one million cubic metres, two of them (Tripoli and Benghazi-south) will have, a capacity of 252,000 cubic metres each. (Kershman, 2001).

The development in desalination must be accompanied with economic studies to achieve lower unit costs. Various factors affecting the cost impose a necessity for a standard format to evaluate and compare desalination technologies for site-specific conditions.

Libya tried during the last twenty years, with more or less success, to introduce the desalination of sea water to overcome its problem of shortage of water. Several plants were thus built close to great urban centres and industrial complexes. Libya has the most important capacity of desalination of sea water in the sub-region and even in Africa with a capacity production of 18000 cubic metres/day but this figure is probably an overestimation of the actual production since most of the desalinisation plants are not in good operating condition.

Table (5.11): Desalination Plants

Location	Capacity Cubic Metres/Day	Location	Capacity Cubic Metres/Day
Zanzur	22500	Ajedabia	35000**
Tajura	11000	Susa	13500
Suq el khamis	42240	Ras lanuf	33000
Zliten	18000	New zliten	30000
.Benghazi	48000	Misurata	30000
Derna	9200	Steel authority Misurata	8500
Tobruk	24000	Zwara	18000*
Sirt	18000*	Total	366,840
Ben Jawad	5900		

Data Sources: Omer M. Salem.1993.the Great Manmade River Project A partial Solution to Libya Future Water Supply. Water Resources Development. 8(4):pp272.

*Replaced by a New Plant with a Capacity of 10000 Cubic Metres/Day

**Presently out of Order

Table (5.12): Desalination Plants from 1975 to 2006

Location	Operation Year	Total Production, Cubic Metres/day
Derna	1975	9,400
Zuara I	1975	13,500
Tripoli west	1976	23,000
Tobruk I	1976	24,000
Sirte	1976	9,000
Zuitina I	1977	5,500
Benjawad	1978	6,000
Benghazi	1978	24,00
Zuara II	1978	4,500
Zliten	1978	18,000
Homs	1980	53,000
Azwitina	1981	30,000
Sussa	1982	13,500
Zuitina II	1983	30,000
Sirte	1986	10,000
Bomba	1988	30,000

Musrata steel	1990	30,000
Zliten	1992	30,000
Deana	1999	5,000
Tripoli west I	1999	10.000
Sussa II	2000	10.000
Tobruk II	2001	40,000
Azwitina	2002	240
Abutraba	2004	40,000
Zawia	2005	80,000
Benghazi	2006	250,000
Zawia	2006	40,000

Data sources: 25 Years of Experience in Operating Thermal Desalination Plants, S.A.Kershman, ELsevier, Desalination 136 (2001)141-145

5.2.2 Distillation Water (The Reuse of Water or Sewage Treatment)

Due to the fact that the reuse of water is a very important factor in supporting the supply of water for the purposes of agriculture. It reduces the exploitation of underground waters. Therefore, the state has taken particular care of the subject of sewage treatment stations. The produced waters were used in irrigation of the areas neighbouring the population concentrations close to the cities. The stations of reusing of sewage water are considered the second important available water source for supply of water Table (5.13) shows the production power of reuse plants.

Actually, the reuse of such waters has positive and negative characteristics. One of the characteristics of such waters is that they are mixed up with waters resulting from the vehicle washing and greasing stations, which leads to the in reduction of oil impurities.

These are very difficult to get rid of, and such waters mostly leave behind a thin layer on the soil. Another negative characteristic is that they are also mixed up with used waters of industries and hospitals.

On the other hand, there are some positive characteristics. For example, they contain solved fertilizers, which are very useful for agriculture. In addition to that, the costs of reused water are very low, and consequently the exploitation of underground water is reduced.

A number of sewage-treated water plants are already in operation or planned for the near future, for example, El-Hadaba El-Khadra plant was established in 1970 in the south of Tripoli city. The treated water was estimated with 91 million in 1990 and increased to 200 million cubic metres in 2000 (Uneop, et al., 1996: 271).

Table (5.13): Production Power of Reuse Plants

Plant	Production Power Cubic Metres/Day
Tripoli	40000
Benghazi	27000
Alzzawya	14200
Alkhums	8000
Zliten	6000
Zanzur	6000
Sebrata	4000
Misurata	3000
Derna	2550
Algaba	2000
Almarj	1800
Albitnan	1500
Shhat	1500
Sebha	1500
Tobruq	1330

Ghadamis	1200
Sussa	1000
Alabrk	1000
Massa	1000
Tarhunah	1000

Data source: Salem, O.M.1992. The Great Manmade River Project. In: Water Sources Development, 8(4).

5.3 FACTORS AFFECTING THE WATER SUPPLY

When discussing the factors affecting the water supply, a difference has to be made between natural supply of water and the economic supply. The natural supply handles the natural water quantities of a certain area at any time. Water natural supply is not subject to prices but only to the different natural factors such as the rains, wells, wellheads, seas, snows and other factors such evaporation and leakage of water.

The economic supply handles the water quantities actually taken from its natural sources and utilized or prepared for final use. That depends on the desire of society or individuals as well as their capability to bear the costs of producing it.

If the producer is an individual targeting profit the produced water quantity would depend, in addition to production cost, on price. But if the state is moved to provide water for the common benefit and in order to keep step with the demand of water as in Libya, then the costs are the basic determinants of water quantities to be taken out and prepared for the final use.

5.3.1 Technology

Technology plays an important role in affecting water supply, and then the use of modern technology helps obtain water with lowest possible costs, whether upon taking out of water from aquifers, or upon production of desalted water and treatment of black water.

5.3.2 The Cost of Water Production

Taking into consideration that the cost of water production is one of the important factors affecting the supply of water, such cost has to be divided into different kinds of costs, such as costs of taking out water from the natural source, water desalination costs, water treatment costs and costs of conveying water from one place to another.

The water supply is connected tightly with the costs of taking water out and conveying it to the places where it is used. So, costs form a basic factor of water supply, because water is considered as a renewable resource commodity. It is a public commodity to be taken out and supplied by the state to fulfil the demands of potable water in cities and dwelling concentrations.

Consequently, the state supplies large quantities of water for this purpose to support prices (the state bears a considerable part of water costs). So, potable water is supplied at reasonable prices in order to protect the needs of people with limited income. Such supply of water does not apply to the needs of water for the purposes of industry and agriculture, then the state is not obliged to provide water for agriculture. It may only construct dams, reservoirs and the like to help save water.

According to the above, the fees of water consumption in the Libyan Jamahirya are considered symbolic (0.25 Libyan Dinars per cubic metre). The state undertakes supporting this utility by covering the expenses. In the following a comparison between water production costs of desalinated water, underground water, surface water and Man-Made River water is made.

5.3.2 .1 The Production Cost of Desalinated Water

By viewing the data below (Table 5.14), it becomes clear that the production cost of desalted water varies from one station to another (0.13-1.07 Libyan Dinars per cubic metre). This variety is due to the difference between the actual production proportion and the designed production from one station to another for the above mentioned reasons.

It is worth mentioning that after making use of modern technologies invented in this field the availability of good management, and the suitable maintenance and operation programs, the current stations could reach their designed capacities and consequently the costs of water desalination, for the purpose of providing water needs for the dwelling concentrations spread along the coast, could be reduced.

5.3.2 .2 The Costs of Underground Water Production

The costs of underground water production are affected by many factors, such as the costs of drilling, maintenance and electric energy. Taking these costs into consideration, information and data in this concern indicate a minimum cost of one cubic metre of underground water amounting 0.011 Libyan Dinars[2] in the

[2] Libyan dinar approximately = £0.60712

region of Benina/Benghazi level land. On the other hand, the maximum cost of one cubic metre in the region of Beida/Green Mountain is 0.068 Libyan Dinars.

5.3.2 .3 The Costs of Surface Water Production

The costs of surface water production are affected by many factors, such as the costs of dam construction. These costs vary between 0.17 and 0.51 Libyan Dinars for one cubic metre of surface water.

5.3.2.4 The Production Cost of the Great Man-Made Rive

The production cost of the Great Man-Made River from the beginning of drilling in the southern region to the beginning of irrigation in the north are estimated to be 0.061 Libyan Dinars for one cubic metre of the Great Man-Made River including variable and constant costs.

On the basis of the above, it becomes obvious that the lowest water costs are those of underground water followed by the costs of the Great Man-Made River waters. The highest water costs are those of desalinated waters.

Table (5.14): Cost of the Water from Different Sources

Name of Data Source	Price of Cubic Metre by Libyan Dinar
Underground Water	From 0.011 to 0.068
Surface Water	From 0.17 to 0.51
Desalination Water	From 0.013 to 1.07
Man- Mad River Water	0.061

Data sources: Brown and Root (Overseas) Limited, 1990. "Estimate of Cost of Water." Report No.(F1321A), The Management and Implementation Authority of the Great Man- Made River Project, Benghazi, Libya, January 1990.

In spite of the fact that the desalinated waters are infinitely available, they are not considered economical in regard of irrigation of agrarian crops due to their extremely high costs. From another point of view, the Great Man-Made River waters are considered rather economical and acceptable. They provide a partial solution to the water problem, but they are not available in large quantities for a long period of time. Consequently, the best solution to be relied on for the long term is the desalted water, then its source is inexhaustible. Therefore, they would form the main source in the future.

5.4 CONCLUSIONS

This chapter has provided an overview of the two types of water supply in Libya. Conventional water is divided into surface water, underground water and the Great Man-Made River project, while non-conventional water is divided into desalination and distillation water. It was found that underground is the main source of water supply in Libya with 87% of the water needs and 13% for surface, desalination and distillation. It also reviewed briefly the factors affecting the water supply and the cost of water production. On the basis of the above, it becomes obvious that the lowest water costs are those of underground water followed by the costs of the Great Man-Made River waters. The highest water costs are those of desalinated waters.

Having presented the supply side of Libyan water, water demand will be discussed in the next chapter.

CHAPTER SIX

WATER DEMAND

6.0 INTRODUCTION

Water, like the blood in our veins, is a necessity to all life forms and pursuits. Consequently, changing global and regional circumstances have increased the need for accurate predictions of both water supply and demand.

In the last few years, domestic water shortage has increased worldwide, water shortage as a result of population growth and increase in the individual agricultural domestic and industrial demand.

Water is a natural resource renewable in limited quantities. We have seen a trend rise in the demand growth. Demographics and rising living standards all contribute to the increase in demand.

Despite the scarcity of water resources, the growth of water demand has a marked impact on the water resources of Libya which suffered serious depletions and quality deterioration (Abufayed and ElghuleL, 2001: 48). This consumption is on the rise as a result of improving economic conditions, urbanization, and improving standards of living.

This chapter is divided into four sections. Section 6.1 of this chapter will discuss water demand for various purposes (agriculture, domestic and industry). Section 6.2 will outline water deficits. The factors affecting the demand for water will be discussed in section 6.3. Finally, the conclusions are provided in section 6.4.

6.1 WATER DEMAND BY SECTOR

Water has many uses, such as in agriculture, domestic and industrial use. Water use has increased significantly in Libya during the last two decades due to population growth, industrial development as well as the growth in irrigated agricultural areas.

Water consumption in Libya is divided into three main types:

- Water demand for the purpose of agriculture
- Water demand for the purpose of domestic use
- Water demand for the purpose of industry

The growth of water demand has a marked impact on the water resources of Libya which suffered serious depletions and quality deterioration (Abufayed and ElghuelL, 2001: 48). The common bench mark for water scarcity is 1000 cubic metres/year/person. In the Middle East and North Africa, 53 % of the people are said to live with less 100 cubic metres/year/person (Jacqueline, 2000). Water availability in Libya is below 1000 cubic metres/year/person. Renewable resources per person were 538 and 154 cubic metres/year/person in 1960 and 1990, respectively, and are expected to shrink further to only 55 cubic meters/year/person in 2025 (Hirji and Ibrekk, 2001).

The data in table (6.1) show huge increases of water consumption in Libya .This increase of water consumption could be explained by the use of water in the different purposes as will be shown later.

However, water consumption of the various purposes depends on under-ground water, which meets 88% of the needs. As can be seen from table (5.1) in the previous chapter.

Table (6.1): Water Consumption during the Period 1995-2005

	Water Consumption for the Purpose of Agriculture (Million Cubic Metres)		**Water Consumption for the Purpose of Domestic (Million Cubic Metres)**		**Water Consumption for the Purpose of Industry (Million Cubic Metres)**		**Total Water Consumption (Million Cubic Metres)**	
Years	Quantity	%	Quantity	%	Quantity	%	Quantity	%
1975	297.10	70.66	122.80	29.21	.55	0.13	450.45	100
1980	657.00	74.83	216.00	24.60	5.00	0.57	878.00	100
1985	1455.00	77.39	380.00	20.00	45.00	2.40	1880.00	100
1990	2164.00	81.38	435.00	16.36	60.00	2.26	2659.00	100
1995	4540.00	87.76	530.00	10.25	103.00	1.99	5173.00	100
2000	4690.00	86.76	568.14	10.51	148.14	2.74	5406.29	100
2005	5060.00	83.29	830.00	13.66	185.00	3.05	6075.00	100

Data sources: General Environmental Authority, 2002:66, 67

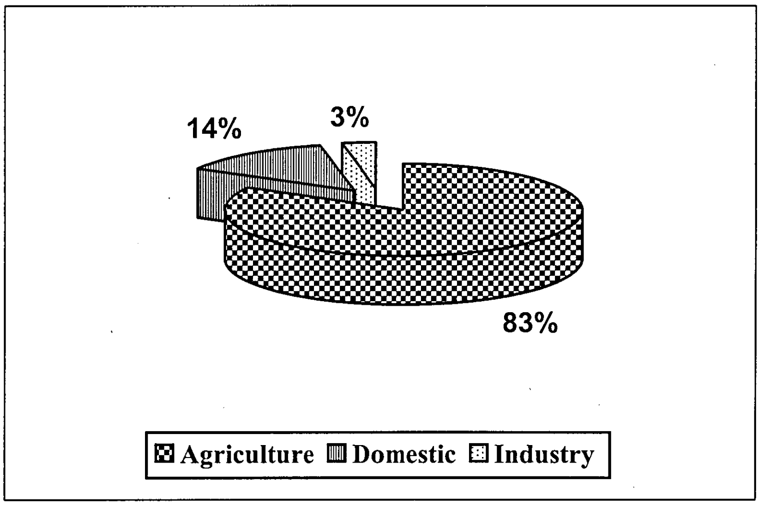
General Authority of the Great Man Made River, 1996: 45

General Authority for Information and Communication1975, 1980.1990,2000,2006

Jamahiriya Statistical Book, the National Corporation for Information and Documentation, 2003

Great Socialist People's Libyan Arab Jamahiriya, General Authority for Information and Communication, Statistics Book, General Authority for Information and Communication Yearly, 200

Figure (6.1): Water Consumption in 2005



Data sources: table (6.1)

6.1.1 Water Consumption for Agricultural Use (Indirect Use)

Agriculture in Libya has developed remarkably during the last two decades. This can be seen in the great increase of the irrigated areas, which have doubled during the period 1975–2005. Where the cultivated area has increased from 282250 hectares in 1975 to 470000 hectares in 2000 (Table 6.2). This means that the cultivated area has increased by 66.5% during this period

When comparing the consumption of water for agriculture purposes with the increase of the cultivated areas during the period of this study, an increase of the water quantities for the purpose of agricultural use is easily noticed. These consumed quantities made 4690.00 million cubic meters in 2000; i.e. 86.76% of the total water consumption of the same year as can be seen from table (6.1).

While the agriculture production increased from 1,137 thousand tons in 1975 to reach 1,779 thousand tons in 2000, the agrarian productivity per hectare decreased from 4 tons/hectare in 1975 to 3.5 tons/hectare in 1980 and 1990, then became 3.7 tons/hectare in 2000.

Table (6.2): Development of the Most Important Indices of the Agriculture Sector and Agriculture Water Consumption

Period	Agrarian Production (Thousand Tons)	Cultivated Area (Hectare)	Hectare Productivity (Tons)	Water Quantity (Cubic Metres/ Hectare)
1975	1137	282250	4	1052
1980	1340	382008	3.5	3507
1990	1580	451057	3.5	3601
2000	1779	470000	3.7	3785

Data source: Hajjaji, S.S (2001), Agricultural Development and Land Settlement in the Kufra Region of Libya, in FAO, Land Reform , Land Settlement and Cooperatives , 1/2, pp.68-88.

Table (6.2) shows consumption of water increasing from 1052 cubic meters in 1975 to 3785 cubic meters in 2000. This means that water consumption per hectare during the period 1975–2000 increased by approximately 260%.

From the above explanation it becomes clear that there is misuse of water in the agriculture sector. While the agrarian productivity per hectare was decreasing, the water consumption per hectare was increasing continuously. This could be explained by all or a part of the following reasons:

- **Nature of earth:** agricultural areas differ in regard of water consumption. If an area, for example, is unlevelled, it would need big quantities of water. The types of soil also affect the water consumption. Heavy soils need less quantity, if compared with light sandy soils, which require bigger quantities of water.

- **Climate:** Climate affects the process of water consumption. If temperatures are high, rains are rare and the dominating winds are dry and hot, crops would need big quantities of water.
- **Irrigation methods**: There are many methods followed in irrigation of agrarian crops; such as irrigation by sprinkling, dripping and under surface irrigation. Also objective irrigation and consumed quantity of water differ from one method to another.

The water needs of agrarian crops depend on the existing crop composition. See table (6.3)

Table (6.3): Water Needs of Some Agrarian Crops

Kind of Crop	Water Needs of Current Irrigation Methods: Cubic Metres/Hectare Per Annual
Citrus	10883
Apple	13000
Pear	13000
Grapes	9000

Data source: National Committee to Combat Desertification, 1999

Water needs of some agrarian crops:

From table (6.3) a clear difference is noticed in the water consumption of one hectare of each crop. A hectare of grapes, for example, consumes 9000 cubic meters of water, while the crop of apples consumes 13000 cubic meters of water. A clear difference in the water consumption of one hectare of the two crops is obvious (estimated with about 4000 cubic meters of water for one hectare).

Misuse of water in agriculture:

As an example of misuse of water in the agricultural sector in Libya, some studies indicate that a hectare of clover in Libya consumes 17250 cubic metres of water annually, while the same hectare of clover in other countries only consumes 10000 cubic metres of water per annum. That means that the water quantity used for irrigation of one hectare of clover in Libya is nearly enough for irrigating two hectares according to international standards FAO (2000).

Actually, the water quantity necessary for one hectare in the Libyan Jamahirya differs from one region to another and according to the method of irrigation used. In order to realize a decrease of the water consumption rates of one hectare in the Libyan Jamahirya, an reorganisation organizing of irrigation should be undertaken and modern technological methods of irrigation have to be exercised to enable saving of water (such as the systems of irrigation by sprinkling or dripping).

Table (6.1) shows agriculture, being the major water consumer, accounts for about 83% of the pumped groundwater in 2005.

Cultivable area is estimated at 3.80 million hectares, accounting for only 2% of the total country area. In 1997 irrigation area was estimated at 2.28 million hectares, that is to say 60% of cultivable area, with 1.93 million hectares of annual crops and 0.35 million hectares in permanent crops (FAO1997).

In 2005 irrigation potential has been estimated at 750000 hectares. However, the development of this potential would have to rely mainly on the use of fossil water. Considering renewable water resources, it is estimated that a maximum of 40 000 hectares could be irrigated in the coastal areas in 2000 (FAO 2005).

Irrigated agriculture is expanding in the north as well as in the oases and along wadis. At present it is estimated that between 350,000 and 400,000 hectares are under irrigation. Their water requirements vary from less than 10,000 cubic metres/hectares to over 20,000 cubic metres/ hectares, depending on the location, type of crop and irrigation method. At the same time, domestic water use varies from less than 150 l/capital/day in small rural settlements, to over 300 l/ capital /day in major cities (FAO 2000).

However, there are three different categories of farming in the irrigation sub-sector as shown in table (6.4)

Private irrigation, generally on 1-5 hectares plots, which receives substantial state support for water equipment, energy, and agricultural inputs. This type of farming is mostly concentrated in the traditional development areas, i.e. the Jifarah Plain, the Jabal al Akhdar, and the Murzuq Basin, and the actually irrigated area covered about 257 000 hectares in 2000. As is shown in table (6.4)

Large-scale state farming, mainly located in the southern areas, where new irrigation schemes have been set up based on highly productive deep wells supplying water to blocks divided into small plots and cultivated by small-scale farmers.

Large-scale state farming, mainly located in the desert areas, operated by state technicians and workers.

As mentioned the total water managed area is approximately 470 000 hectares, all equipped for full or partial control irrigation (FAO 2005). On almost the entire area sprinkler irrigation is practised, because of the sandy soils prevailing in most areas of Libya. The costs of installing sprinkler irrigation on a farm amount to about US$10 000/ hectares. It was estimated that of the total area of

470 000 hectares, 316 000 hectares was actually irrigated in 2000. As can be seen from table (6.4) about 99 percent is irrigated using groundwater, while the remaining 1 percent is irrigated by treated wastewater and surface water (FAO 2005).

Because of the importance of private irrigation, representing some 81 percent of the net irrigated area in Libya, the figure of 316 000 hectares should be considered a rough estimate, probably underestimated. With a cropping intensity that varies from 1.3 to 1.5 according to the area, the total harvested irrigated area (winter + summer irrigation) is estimated to range from 440 000 to 500 000 hectares (FAO 2005).

Yields from rain fed as well as irrigated agriculture are generally low. Apart from the aridity of the climate, which reduces rain fed yields, this is due to prevailing shallow, coarse soils with limited natural fertility and high erosion risks. The average yield of irrigated wheat and barley is much lower than the yields obtained in other Mediterranean countries. The yields for irrigated fruits, vegetables and oil crops are generally also lower than in the surrounding countries, but for these crops the differences are smaller. It is known that large areas of fodder (mainly berseem) are cultivated and irrigated in the winter.

It is estimated that at least 80 percent of agricultural production depends on irrigated agriculture. There are no statistics of cropped areas subdivided by rain fed or irrigated agriculture (Table, 6.4).

Table (6.4): Area Actually Irrigated in Libya in Hectares in 2000

Area	Irrigated Area in Hectares			Private Irrigation % of total
	State Schemes	Private Irrigation	Total	
Al jabal akhder	0	24000	24000	100
Al kufrah-as sarir	18500	8500	27000	31.5
Jifarah	0	142000	142000	100
Hamada el hamra	22000	15000	37000	40.5
Murzuq	18500	67500	86000	78.5
Total	59000	257000	316000	81.3

Data sources: CIA.The World Fact Book-Libya.

International small Hydro Atlas (http://www. Small-hydro.com)

Table (6.5): Estimated Crop Yields in Libya

Crop	Yield in kg/ hectares	
	Rained	Irrigated
Wheat	650	1400
Barley	450	750
Millet	1200	-
Dates	2800	8600
Potatoes	-	7300
Pulses	600	1500
Citrus	-	10500
Apples	8300	20000
Grapes	2300	10400
Vegetables	6700	13000
Olives	700	2200
Groundnuts	-	1800

Data sources: CIA.The World Fact Book-Libya.

International small Hydro Atlas (http://www. Small-hydro.com)

Libya already experiences a deficit in food production and depends mainly on food imports. In the middle of 1990s Libya imported about 60 % of its food requirements (Schlierhake, 2004: 211). Agricultural production constitutes only a small percentage (8.6 %) of the Gross Domestic Production of Libya (CIA, 2004). Arable land is only 1.815 million hectares, out of which, permanent crops cover 335,000 hectares (figures for 2001, FAO, 2002: 4). The areas under irrigation were estimated at 435,000 hectares in 1989-1991 and increased to 470,000 hectares in 1999-2001 (FAO, 2002: 17). These areas include large scheme project, settlements and smallholder farms, while most of cultivated lands are under rain fed agriculture and pastures (Bin-Mahmoud et al., 2000). Most of the arable and pastoral lands occupy the northern semi-arid parts of Libya, while deserts in southern Libya are subject to frequent periods of drought. Principal crops cultivated in Libya are wheat, potatoes, barley, citrus fruits, dates, and olives (Table, 6.5). With the depletion of non-renewable groundwater resources, irrigated areas are in Libya unlikely to increase, but may decrease. Imbalance between rapidly growing population and food-production capability can be observed by wheat production, consumption and decreasing of self-sufficiency in Libya (Table 6.6).

Table (6.6): Growth of Wheat Requirements in Libya during the Period 1990-2000

Year	Population	Wheat Production	Amount Consumed	Gap	Self ratio Sufficiency
1990	4,230	185	682	427	27%
1995	4,400	185	830	645	22%
2000	5.090	185	1,010	825	18%

Data source: National Committee to Combat Desertification, 1999

Precipitation across Libya is mostly <100 millimeters /year expressing a great severity of dryness and drought conditions with even some years experience no precipitation at all. Distribution of total annual precipitation over time and space is clearly expressing the scarcity of precipitation over most parts of Libya. An increase in precipitation variability can rapidly reduce agricultural productivity and alter the composition of steppes and grassland. Libya is chiefly a desert country characterized by arid and semi-arid climate types which played a substantial role in determining land uses and in forming the sensitive water balance rarely achieved in most areas. Under these limitations, the various drought factors produced specific chemical properties and soils which are naturally and characteristically fragile. Agricultural land is, therefore, limited to less than 2 % of Libya's total area. More over, these factors had implications on the composition and distribution of the natural plant over which only produces fodder for 35 % of animal food requirements (National Committee to Combat Desertification, 1999). Precipitation is generally inadequate to meet the water demand of crops and is considered as the most limiting factor for land use especially due to the high potential evaporation in Libya. Hot, dry sandstorms called Gibli have direct and indirect implications on food crops in Libya. For example the sand storm blown on 24-28 June, 1994, seriously affected crop production: 24,735,000 Libyan dinars 17 loss of vegetable, 48,446,000 Libyan Dinars of fruit, and 7,600,000 Libyan Dinars of beans (Kredegh, 2002: 127). This means a total loss of 90,579,000 Libyan Dinars by sandstorms in only four days. Indirect negative effect of sandstorms can be observed through soil erosion in northern parts of Libya. The areas which are affected by wind erosion in Libya are 859,964 hectares (Gneral Environmental Authority, 2002: 210) Variability of harvest and production and cropping areas of two major food crops in Libya were from 1968-2001 to detect the effect of climate change on food crops. Wheat production does not meet the current demand, and each year additional amounts have to be imported. The rapid growth of population and the limited area for agriculture as well as a decreasing economically active farm population (Table ,6.7) increase the vulnerability of food production to climate change in Libya.

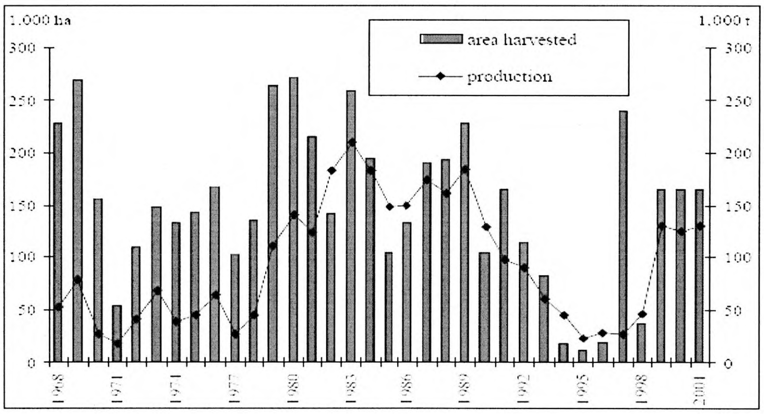
Table (6.7): Population and Percentages of Economically Active Population

Year	Population in Agriculture (1,000)	% of Economically Active Population
1990	783	11.0%
1995	697	8.0%
2001	561	5.6%

Data source: FAO, 2002: 20

Inter-annual variabilities of wheat harvest area can be seen in Libya (Figure, 6.2) explained mainly by precipitation inter-annual variabilities because the irrigated area is limited and most of wheat area is cultivated under rain fed conditions.

Figure (6.2): Harvest Areas and Production of Wheat in Libya, 1968-2001



Data source: 1968-1990 Agriculture Research Center:, 1992. 1991-1998: Elzaedy and Eltaher, 2000. 1999-2001: FAO, 2002

The critical precipitation limits of wheat were some 30% higher than those for barley. Additionally, barley ripens can be harvested earlier than wheat; these characteristics make barley less vulnerable to arid conditions during the early onset of summer (Swearingen, 1992: 406).

Cultivated as rain fed agriculture in Libya, barley relies mainly on precipitation. As result, barley is highly vulnerable to climate changes, seasonal shifts, and precipitation patterns. Any warming leads to an increasing water shortage. Increased temperatures would increase evapotranspiration which is likely to increase crop water requirements and lower yields. Variabilities of precipitation negatively affect barley. Mean annual barley production was 117,656 t from 1968-1990, while its production was very low at 100,000, 71,000, 87,000, and 83,000 t in 1979, 1980, 1984, and 1985, respectively (Agriculture Research Center (Tripoli), 1992).

Water used for irrigation is an intermediate good for the production of agricultural crops. The diversity of agricultural results in different water values depending on its use for the production of different crops.

There is a last point in regard of using water for agricultural purposes, namely that the official authorities responsible for making water available in the Libyan Jamahiriya do not supply water to farmers. They undertake themselves making available their water needs by drilling wells in their farms. In spite of this policy, the official authorities, according to the plan of the Great Man-Made River Project, will provide farms (to be founded by the said plan) with waters of the Man-Made River against a certain cubic metre price.

6.1.2 Water Consumption for Domestic Use (Direct Use)

Consumption of water for the purpose of drinking and other human purposes consists of using water for drinking, cooking, cleaning, washing and all other domestic and human uses. The data stated in the table (6.1) show, that the consumption of drinking water increased from 122.8 million cubic metres in 1975 to 830.0 million cubic metres in 2005.

Even though the consumption of potable water increased, it decreased sharply as a proportion of the total water consumption; namely from 29.21% in 1975 to 13.66% in 2005. This could be explained by the very high increase of water consumption rates of the agricultural and industrial sectors, when compared to the consumption of drinking water. The data of table (6.8) show, that the share of water of an individual increased from 55.07 cubic metres in 1975 to 120.45 cubic metres in 1995. This share decreased later; namely in 2000 to reach 112.73 cubic metres.

Table (6.8): Water Consumption in Total and Per Person during the Period 1975-2005

Period	Population (Million) (1)	Water Consumption for the Purpose o Domestic (Million Cubic Metres) (2)	The share of Water of an Individual 2÷1=3	*Number of Litres of Water Per Person/Day
1975	2.23	122.80	55.07	150.9
1980	2.75	216.00	78.55	215.21
1985	3.32	380.00	114.46	318.59
1990	3.82	435.00	113.87	311.97
1995	4.40	530.00	120.45	330
2000	5.04	568.14	112.73	308.85
2005	6.09	830.00	136.29	373.39

Data source: table (4.3) and (6.1)

* Number of Litters of Water per Person / Day = The Share of Water of an Individual / 360 x1000

Some studies suggest that water needs depend on the type of climate, activity practised and cultural progress. They indicate, furthermore, to the fact, that the average of the daily needs of an individual residing in the countryside varies between 40 and 200 cubic metres of water, while the average needs of an individual residing in a city vary between 200 and 300 cubic metres daily.

The increase of water consumption could be attributed to a group of factors such as;

firstly; diffusion of health consciousness and improvement of living standards.

secondly; decrease of water price and the possibility of evading payment of water bills.

thirdly; popular mis-understanding of the importance of rationalization of water consumption.

In Libya about 90% of the population live in urban centres see (Table, 3.7) in chapter three) varying in size from 5 000 to 1 000000 inhabitants, and depend for their domestic water supply on municipal sources with house connections. Various surveys have been conducted to determine the average water consumption per capita, which was found to range from 150 to 300 l/ capita/day, depending on the size of the city, location, and age of the supply network.

In rural areas, people depend to a certain extent on private water supply sources, usually wells, rainwater reservoirs and springs. The average per capita consumption falls between 100 and 150 l /capita/day.

In addition, in Libya the percentage of household access to drinking water is about 80%. However this figure does not tell us about the availability of water in term of quantity and quality because of the water shortages that happen in the main cities; for the more, the wells which supply a great part of the water resource for the coastal cities are polluted by sea water intrusion. Libya projects to drinking water of 100% within 7 years (FAO 2005).

In Libya also 485 of the houses are connected to a waste water network; but this rate varies according to shabbiest: it varies between 3000 cubic meters/day and 120000cubic meters/day, but only 40 of them are in service, reducing the total capacity of treatment of 400000-500000cubic meters/day to nearly 184000cubic meters/day (FAO 2005).

6.1.3 Water Consumption for Industrial Use (Indirect Use)

In the Libyan state, water for industrial use is estimated at around 2% in 2005 (table (6.1)). The use of water for industrial purposes is a small part of the costs of production, in comparison with other factors of production, such as raw materials, labour and capital. Very often the technologies and type of industrial output are the determining factors for the quantities of water used in the production process.

By viewing the data stated in table (6.9) it becomes clear that the production value (taking into consideration the prices of 1980) increased from 80.1 million Libyan Dinars in 1975 to 355.1 million Libyan Dinars in 2005. This means, the industrial production increased approximately four and half times during the period 1975–2005. This industrial expansion was accompanied by a huge increase of water consumption. The rate of water consumption of the industrial sector increased against the total consumption from 0.13% in 1975 to 2.74% in 2005 as shown in the table (6.1). And if we consider water consumption in general, we would notice, that it increased from 0.55 million cubic metres in 1975 to 60 million cubic metres in 2005 as shown in table (6.9).

Table (6.9): Water Consumption for Industry and Developing Industrial Production during the Period 1975-2005

Years	Value of Industrial Production by Price 1980 (Million Dinar)	Growth Rate of Industrial Production %	Share of Industry from Total Water /Million Cubic Metres	Rate of Industry Consumption Growth
1975	80.1	-	0,55	-
1985	213.9	166	45,00	809
1995	278.9	30	103.00	800
2005	355.1	28	185.00	333

Data sources: General Authority for Information and Communication1975, 1980.1990,2000,2006

Jamahiriya Statistical Book, the National Corporation for Information and Documentation, 2003

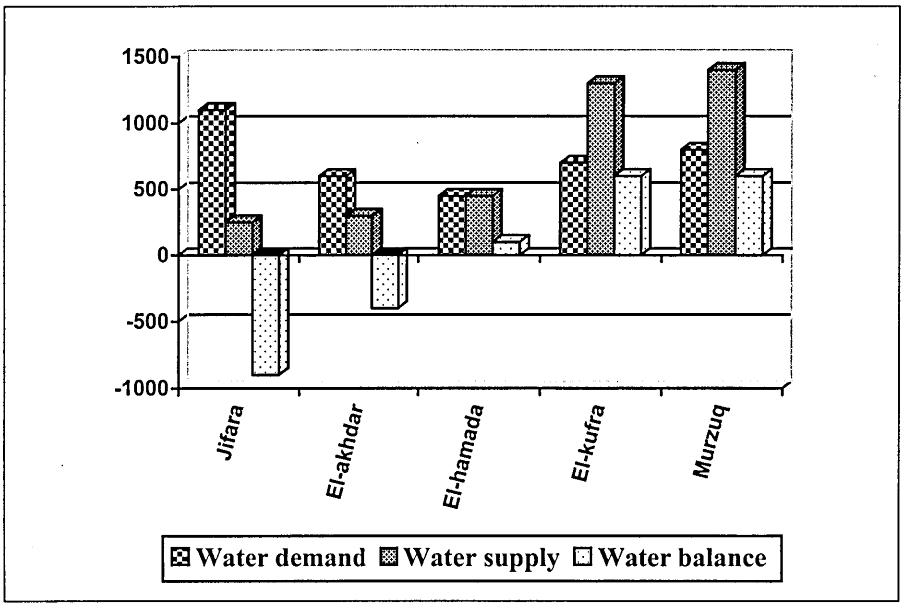
This increase of water consumption in industry could be explained by the expansion of industrial capacities of the different industries, particularly during the period 1975–2000, which was the scene of industrial expansion all over the country. The industrial sector grew rapidly during the period 1975–2005, which clarifies the increase of water consumption of this sector.

It is worth mentioning that the water used in industry is obtained from two sources; namely desalination of seawater and underground water. Actually, the authorities responsible for providing water in Libya only supply water for industrial use within restricted limits. The industrial projects are even forced to source their needs. Therefore, these projects drill their own wells, perform the treatment of water alone and bear the costs resulting from these processes.

6.2 WATER DEFICITS

Determining the water balance of any bed requires availability of adequate data about the water feeding[1] quantity as well as the water consumption[2]. Water situation is considered in a balanced condition, if the consumption quantity and feeding quantity are equal. If the consumption quantity is bigger than the feeding quantity, this would mean that there is a deficit of water balance. On the contrary, if the consumption quantity is smaller than the feeding quantity, that would mean an overabundance in the water balance (Table, 6.10).

Figure (6.3): Water Balance in the Ground Water Basins in Libya, 2000



Data source: Ben-Mahmoud, R., Mansur, S. and AL-Gomati, A. 2000. Land Degradation and Desertification in Libya, Land Degradation and Desertification Research Unit. Libyan Centre for Remote Sensing and Space Science. Tripoli, Libya

[1] Feeding is in fact the ever renewed annual flow into the water reservoir bed.
[2] Consumption is the water quantity taken out yearly from the reservoir bed.

Table (6.10): The Balance of Water (Million Cubic Metres)

Reservoir	Year			
		1985 (Million Cubic Meters)	**1995 (Million Cubic Meters)**	**2000 (Million Cubic Meters)**
Jifara	**Supply (feeding)**	**279.5**	**279.5**	279.5
	Demand (consumption)	**532**	**677**	1200
	Balance	-252.5	-397.5	**-920.5**
Hamada Elhamra	**Supply (feeding)**	**328.5**	**328.5**	328.5
	Demand (consumption)	**191.9**	**267.1**	455
	Balance	136.6	61.4	**-126.5**
The Green Mountains	**Supply (feeding)**	**337.5**	**337.5**	337.5
	Demand (consumption)	**171.5**	**261**	6000
	Balance	166.0	76.5	**-262.5**
Kufra/Sarir	**Supply (feeding)**	**535**	**563**	563
	Demand (consumption)	**221.5**	**542**	563
	Balance	313.5	21	**0.0**
Morzuk	**Supply (feeding)**	**771**	**771**	771
	Demand (consumption)	**385.4**	**566.9**	771
	Balance	385.6	204.1	**0.0**

Data source: Ben-Mahmoud, et al., 2000

In the following an idea about water balance is given by diagnosing the data shown in the table (6.10):

- **Reservoir Bed of the Level Land of Jifara**:

The annual supply (feeding) quantity of the reservoir bed of the level land of Jifara is estimated with 279.5 million cubic metres and the annual consumption quantity with 1200 million cubic metres in 2000. This means, there is a yearly deficit of 920.5 million cubic metres of water. The studies related to water consumption of the reservoir bed of the level land of Jifara indicate the fact that consumed water quantities for agricultural, domestic and industrial use are continuously increasing as shown in Table (6.11). As long as the estimation of annual feeding are within the limits of 279.2 million cubic meters, an annual deficit of water will remain existing, which means continuous decrease of reserve water in the reservoir bed of the level land of Jifara. This deficit could be attributed to the following reasons:

- Half of the population of Libya is concentrated in these regions.
- The region includes over 60% of the cultivated area of the country.
- Increase of the factories consuming water.

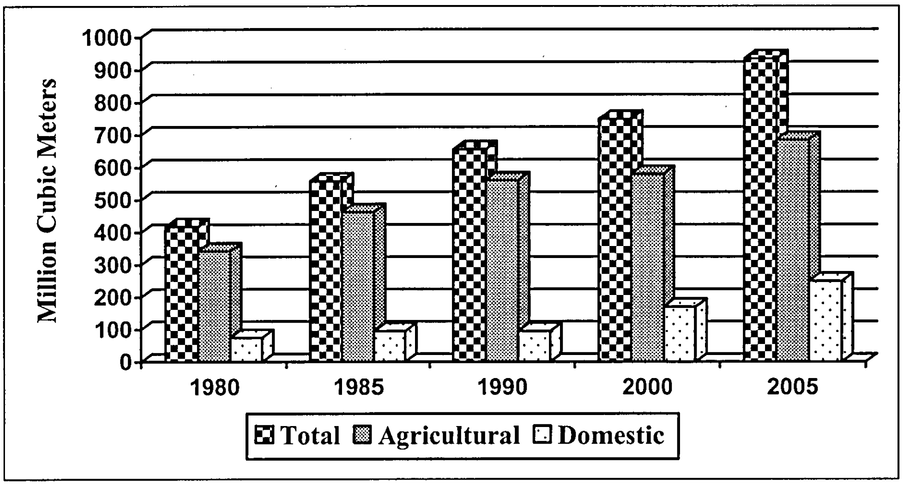
Table (6.11): Water Consumption in Jafari Plain

Years	Agricultural Consumption Million Cubic Metres	Domestic and Industrial Million Cubic Metres	Total Consumption Million Cubic Metres
1980	343	75	418
1985	463	95	558
1990	561	95	656
2000	580	170	750
2005	685	250	935

Data source :National Scientific Research Authority, 1999:39

El- Rejibi, 1998:13, and General Environmental Authority, 2000-2005

Figure (6.4): Water Consumption in Jafari Plain



Data sources: table (6.11)

- **Reservoir Bed of the Green Mountains:**

The reservoir bed of the Green Mountains is suffering nowadays under deficit of water, which reached 262.2 million cubic meters annually. This deficit is not as bad as that of the reservoir bed of the level land of Jifara and could be explained by the increase of population growth as well as the agrarian water consumption.

- **Reservoir Bed of Hamada Elhamra:**

Though the water balance of the reservoir bed of Hamada Elhamra has an overabundance of 61.4 million cubic meters in 1995, but in the years to come the overabundance it turn over to a deficit 126.5 million cubic meters in 2000 due to the great increase of population growth, the existence of many industrial projects and a huge number of palm trees, in addition to the different agrarian projects. Some studies suggest that the region is facing the possibility of becoming invaded by seawater. That would require necessarily a rationalization of water consumption.

- **Reservoir Bed of Morzuk**:

The consumed water of the reservoir bed of Morzuk is estimated at about 566.9 million cubic meters yearly. The increase of water consumption of the reservoir bed of Morzuk is attributed to the existence of many agriculture projects; such as the projects of Maknusa, Tahala, Arial, Dion, Barjoua, Irowana, Shore Valley and Life Valley. On the other hand, the water quality available for abstraction amounts to about 771 cubic meters per annum. Therefore, it was decided to convey the quantities exceeding the region needs–as on of the phases of the great man-made river project – to the north-west coast, which suffers great deficit in its water sources. The water quantity to be conveyed is estimated at ca. 204.1 million cubic meters annually.

- **Reservoir Bed of Kufra/Sarir**:

The water quantity, which could be taken out yearly in the region Kufra/Sarir, is estimated with about 563 million cubic meters for a period of nearly fifty years. The water already consumed is estimated with ca. 450 million cubic meters per annum. It was decided to convey a part of the water of the reservoir bed of Kufra/Sarir yearly to the north-east coast due to the deficit of water there. The water quantity to be conveyed yearly is estimated with approximately 21 million cubic meters.

The water researches indicate that Libya will face extreme deficit in water resources, among those highly populated cities due to increase consumption of potable water and other purposes beside the shortage of feeding water and renewable resources to the ground water reservoirs. Therefore, the different desalination techniques are considered the best way replacement to save all the water demands in Libya.

Water problems in Libya are diverse and changing as the gap between supply and demand widens. Water issues are linked to scarcity, misdistribution, and sharing. The development and management of water resources in Libya presents a challenge for water managers and experts.

The gap between available water supply and demand was first observed in the domestic sector. The gap is more likely to widen in the future in the municipal, agricultural and industrial sectors unless adequate measures are taken.

The country is reliant for its water supply on ground water sources accounting for 87% of the total, and 13% form other sources in 2005 (Table, 5.1, chapter five).

According to water balance of the groundwater basins in Libya, a severe deficit in water supply occurs in the Jifara plain basin and moderate deficit in Jebal El-Akhdar basin explained by concentration of population in northwestern and northeastern Libya. While there is no deficit water in the southern basins (El-Kufra-Serir and Murzuq), this water is not renewable (Figure, 5.3). Groundwater in southern Libya is from last pluvial period up to 8000 years ago. UN research groups estimate the amount of groundwater in El-Kufra basin with 200 billion cubic meters and in Sarir 15 billion cubic meters (Schliephake, 2004: 210).

In order to face the deficit in the reservoir bed of the level land of Jufra and Green Mountains, some desalination stations were built. Also a huge proportion of black water was brought under control by reusing it, after treatment, in the process of agricultural production. But in spite of those efforts, the water deficit is continuously increasing. At the present time, the water problem in the Libyan economy is to be seen as an unfair distribution of water among the Libyan regions. For example; the regions with high population density have water deficit, while the regions with low population density have an overabundance of water. In order to reduce the water deficit in the northern areas with relatively high population density, the Great Man-Made River Project is aiming to convey huge quantities of water from the south to the north; i.e. to the coastal regions. This project is considered a partial solution of the low supply of water in the northern regions.

6.3 FACTORS AFFECTING THE DEMAND FOR WATER

- **Growth of Population**

The growth of population is one of the most important factors affecting the demand for water. Whenever the growth of population increases, the demand for water increases as well. Therefore, the increase of population growth is considered an important factor in regard of water demand increase.

- **Living standard and civilization**

There is a direct relationship between the individual living standard and his consumption of water. It is well known, that Libya has experienced a tangible improvement in regard of living standards due to the increase of income. The way of life has changed, such as; the use of electric washing machines, care of cleanliness and public health. All that led to increase of water consumption.

- **Industrial expansion**

The increase in the number of industrial establishments and their capacities leads to increase of needed water required, particularly in industries needing big quantities of water such as food industries.

- **Agriculture expansion**

Agriculture in Libyan Jamahirya depends nearly completely on permanent irrigation due to the prevailing climatic condition, mainly the high temperatures leading to increase of the degree of evaporation and low rainfalls varying from year to year. As a result of the agrarian expansion in the form of increasing cultivated areas from 282,250 hectares in 1975 to 470,000 hectares in 2000, the consumed water quantity for agriculture purposes increased as well. It became obvious that the high population growth led to an increase of water demand with a much higher rate than that of the population growth itself. While water consumption increased directly and indirectly from 450 million cubic meters in 1975 to 6075.00 million cubic meters in 2000 with a rate of 13.0%, the population increased from 2.23 millions to 6.09 millions with a rate of 3.50% during the same period of time.

The data in Table (6.11) show that the demand for water for direct and indirect use increases with a rate higher than the rate of population growth. When population growth increases by 1%, a water demand for agriculture purposes with 3.5% is created against rate of 2.18% of potable water. The rate of water demand for industrial purposes reach 9.08%, which could be attributed to the factors affecting water demand.

Table (6.12): Population Growth and Growth of Demand for Water during the Period 1975-2000

	Growth Rate	The Relationship Between Population Growth and Demand for Water
Population Growth	4.04%	1%
Demand on Water for the Purpose of Agriculture	14.14%	3.5%
Water Consumption for the Purpose of Domestic use	8.79%	2.18%
Water Consumption for the Purpose of Industry	36.68	9.08%
Total Demand for Water	13.07%	3.24%

Data sources table (6.1)

Briefly, the difference between the rates of population growth and those of water consumption for the different purposes make it necessary to give attention to reducing the wasted water quantities, especially in the agriculture use, which consumed over four times of the potable water. In the same time, the water consumed for agriculture purposes could not be reused like the water used in industries and domestic purposes.

From the above, the importance of the problem to be reconsidered, in order to find out solutions, becomes clear. The problem indicates that whenever the population growth increases by 1%, the water demand increases by 3.24%. This relation led to appearing of the problem of water deficit, then the level of underground water in coastal areas decreased, and consequently the different replacements have to be studied in order to make water available at least for the direct use (drinking water).

6.4 CONCLUSIONS

This chapter discussed the characteristics of direct and indirect water demand from 1975 to 2005. Direct demand is the demand for water for domestic use. Indirect demand is the demand for water for agriculture and industry.

The date from 1975 to 2005 shows that:

- Huge increase of water consumption in Libya.
- The agricultural sector had the highest consumption quantity in Libya (86%), the domestic sector consumed 12%, and the industrial sector used only 2% representing the lowest portion of the total water withdrawn.
- There is a deficit of water balance in the north.
- The most important factor affecting the demand for water is the growth of population.

Estimation and forecasting using Box-Jenkins modelling will be subject of the next chapter.

CHAPTER SEVEN

ESTIMATION AND FORECASTING USING BOX-JENKINS MODELLING

"Until not so long ago econometricians analysed time series data in a way that was quite different from the methods employed by time series analysts ... Neither group paid much attention to the other until the appearance of types of disquieting ...studies. The first set of studies claimed that forecasts using the econometricians' methodology were inferior to those made using the time-series analysts' approach ; the second type claimed that economic data in fact are not stationary , and this could lead to serious problems with traditional statistics ... These revelations caused econometricians to look very hard at what they were doing, leading to extensive research activity ... that has markedly changed and improved the way in which econometricians analyse time-series data "(Kennedy, 1992:247).

7.0 INTRODUCTION

One of the main objectives of econometric modelling is to predict what is going to happen in the future. This important exercise in the macro econometric context is called forecasting. Forecasting means that the model will solve its endogenous variables beyond the originally utilised set of data. This forecasting exercise needs the predetermined variables of the model for the forecast period.

In this chapter the model of Libyan demand for water outlined in the literature review will be estimated. As mentioned before, the aim of this study is to investigate the total water demand in Libya in the future, and the demand for water for agricultural, domestic and industrial use. The Box-Jenkins approach will be used to estimate the model and forecast.

The rest of this chapter is divided into three main sections. First, the Dickey-Fuller test will be used to check the stationarity of the variables and the order of integration of each individual variable in section 7.1. Second, the ARMA model will be estimated in section 7.2. The results of forecasting water demand will be discussed in section 7.3. Finally, section 7.4 will summarise the main points discussed in this chapter.

7.1 ARIMA FORECASTING MODELS

The Box-Jenkins approach to modelling Autoregressive Integrated Moving Average (ARIMA) processes was described in a highly influential book by statisticians George Box and Gwilym Jenkins in 1970. An ARIMA process is a mathematical model used for forecasting. Box-Jenkins modelling involves identifying an appropriate ARIMA process, fitting it to the data, and then using the fitted model for forecasting. One of the attractive features of the Box-Jenkins approach to forecasting is that ARIMA processes are a very rich class of possible models and it is usually possible to find a process which provides an adequate description of the data. The original Box-Jenkins modelling procedure involved an iterative three-stage process of identification, estimation and diagnostic testing.

This section examines stationary and nonstationary time series by formally testing for the presence of unit roots. Various Box-Jenkins Autoregressive Integrated Moving Average (ARIMA) models are estimated over the period 1975-2005 for total water demand and demand for water for agriculture, domestic and industry use.

The ARIMA models provide a useful framework to understand how the water time series is generated. Unlike univariate smoothing models which are more commonly used, the ARIMA approach requires a water demand time series to be tested for nonstationarity prior to undertaking estimation and forecasting (see Hill et al., 2000). If a series is nonstationary (that is, the series has a mean and variance that are not constant over time), the series has to be differenced to transform it to a stationary series, before generating forecasts. A stationary water demand series typically provides better and more reliable forecasts.

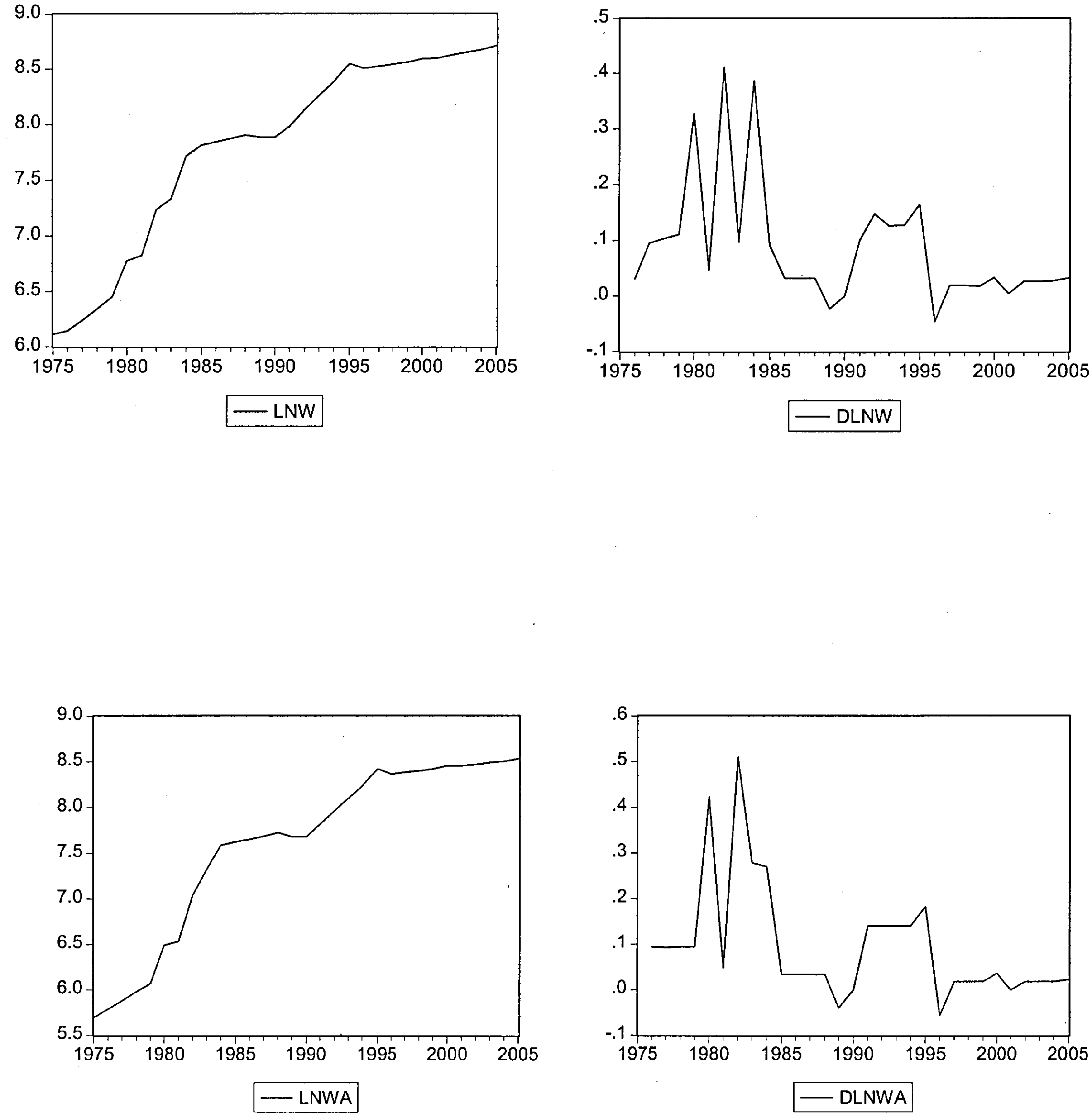
The work of Box and Jenkins (1970) shifted professional attention in time series modelling away from stationary processes to a class of nonstationary processes and the related ideas of the order of integration necessary to obtain stationary series. Furthermore, the Box-Jenkins method is popular because of its generality since it can handle any stationary or nonstationary time series. In the identification phase, a general class of models applicable to a particular situation is examined with the aid of the sample correlograms, and autocorrelation and partial autocorrelation functions.

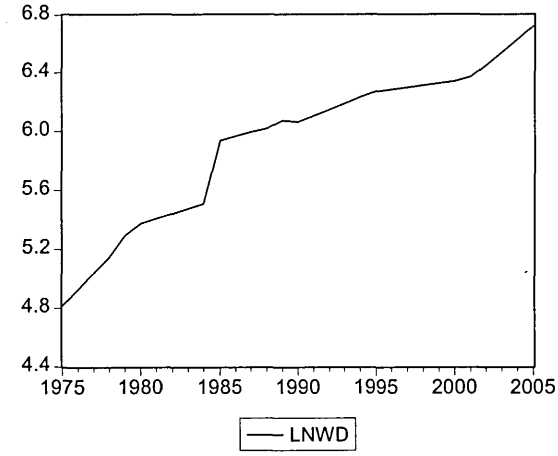
7.1.1 Testing for Stationarity

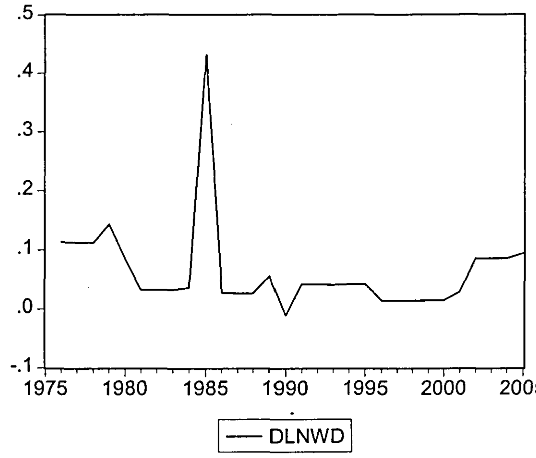
7.1.1.1 Graphs of Variables

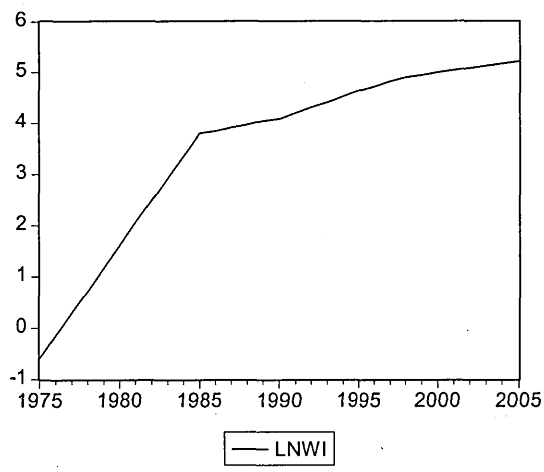
The first method which can be used to check stationarity of the variables is to graph the series. The graphs of these variables in logarithm form are shown in figure (7.1).

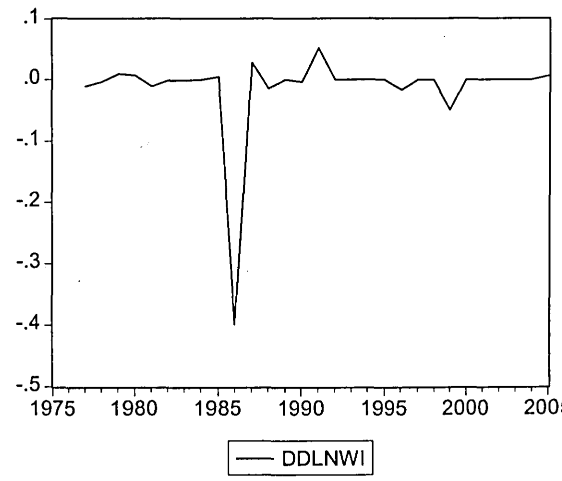
Figure (7.1): Graphs of the Variables $\ln W$, $\ln W_A$ and $\ln W_D$ in Level and in First Differences. Graphs of the Variable $\ln W_I$ in Level and Second Differences.











According to the above graphs, the results indicate that the first differences of total water demand and demand for water for agricultural and domestic use are stationary. Hence, the variables are integrated of order one. The second difference of demand for water for industrial use is stationary. Hence, the variable is integrated of order two.

The original time series in logarithm form is now checked for stationarity using the augmented Dickey- Fuller (ADF) test for unit roots.

7.1.1.2 The ADF-Test for Difference Versus Trend Stationarity

The restricted model assumes the time trend is zero and the series for all variables are difference stationary. As shown in tables (7.1), (7.2), (7.3) and (7.4), the series are transformed by taking appropriate differences to render the series stationary. A detailed explanation of the test procedure is given in Gujarati (2003).

Table (7.1): $\ln W$

Wald Test:				
Equation: Untitled				
Null Hypothesis:	C(2)=0			
	C(3)=0			
F-statistic	3.428872		Probability	0.088313
Chi-square	6.857743		Probability	0.072424

$$\Delta Y_t = \alpha_0 + \lambda t + \theta Y_{t-1} + \delta_2 \Delta Y_{t-1}$$

d ($\ln W$) c Trend $\ln W$(-1) d ($\ln W$(-1))

$$H_0 : \theta = \lambda = 0$$

$$F = 3.43 < F_c = 7.24$$

We can not reject H_0, because the F-statistic is less than the 5% critical value, then we can say that we are 95% confident that the series $\ln W$ follows a difference stationary process.

Table (7.2): $\ln W_A$

Wald Test:				
Equation: Untitled				
Null Hypothesis:	C(2)=0			
	C(3)=0			
F-statistic	4.717876		Probability	0.068265
Chi-square	9.435753		Probability	0.078934

$$\Delta Y_t = \alpha_0 + \lambda t + \theta Y_{t-1} + \delta_2 \Delta Y_{t-1}$$

d ($\ln W_A$) c Trend $\ln W_A$ (-1) d ($\ln W_A$ (-1))

$$H_0 : \theta = \lambda = 0$$

$$F = 4.72 < F_c = 7.24$$

We can not reject H_0, because the F-statistic is less than the 5% critical value, then we can say that we are 95% confident that the series $\ln W_A$ follows a difference stationary process.

Table (7.3): $\ln W_D$

Wald Test:				
Equation: Untitled				
Null Hypothesis:	C(2)=0			
	C(3)=0			
F-statistic	1.430434		Probability	0.258117
Chi-square	2.860869		Probability	0.239205

$$\Delta Y_t = \alpha_0 + \lambda t + \theta Y_{t-1} + \delta_2 \Delta Y_{t-1}$$

d ($\ln W_D$) c Trend $\ln W_D$ (-1) d ($\ln W_D$ (-1))

$$H_0 : \theta = \lambda = 0$$

$$F = 1.43 < F_c = 7.24$$

We can not reject H_0, because the F-statistic is less than the 5% critical value, then we can say that we are 95% confident that the series $\ln W_D$ follows a difference stationary process.

Table (7.4): $\ln W_I$

Wald Test:				
Equation: Untitled				
Null Hypothesis:	C(2)=0			
	C(3)=0			
F-statistic	5.0331		Probability	0.1358000
Chi-square	1.0132		Probability	0.1263400

$$\Delta Y_t = \alpha_0 + \lambda t + \theta Y_{t-1} + \delta_2 \Delta Y_{t-1}$$

$$d(\ln W_I) \quad c \quad \text{Trend} \quad \ln W_I\,(-1) \quad d(\ln W_I\,(-1))$$

$$H_0 : \theta = \lambda = 0$$

$$F = 5.03 < F_c = 7.24$$

We can not reject H_0, because the F-statistic is less than the 5% critical value, then we can say that we are 95% confident that the series $\ln W_I$ follows a difference stationary process.

7.1.1.3 Unit Root Test

Another method which can be used to check stationarity of the variables is the ADF test which is calculated with and without a time trend for water demand for agricultural, industrial and domestic use respectively for lag length of one. Each of the calculated statistics exceeds the critical value. The value of the test statistics with a 5 per cent critical value, as tabulated in Mackinnon (1991), is included in table (7.5), so the null hypothesis of a unit root is not rejected, which implies that each of the four water demand series is nonstationary in its level. The first differences of total water demand and demand for water for agricultural and domestic use are stationary. The second differences of demand for water for industrial use is stationary. Table (7.5) indicates the stationarity of all the variables.

Table (7.5): Unit Root Test

	Level		First difference	Second difference	
	With trend	Without trend	Without trend	Without trend	
Variable	ADF	ADF	ADF	ADF	Conclusion
$\ln W$	-0.71	-2.58	-4.51	–	I(1)
$\ln W_A$	-0.78	-2.84	-3..77	–	I(1)
$\ln W_D$	-2.19	-1.74	-3.52	–	I(1)
$\ln W_I$	-2.59	-2.91	-1.39	-3.72	I(2)

5% critical values.

Without time trend ADF = -2.97

With time trend ADF = -3.57

Parameter estimation in phase two involves fitting various autoregressive (AR) models of order p and moving average (MA) models of order q. The best fitting parsimonious model is selected, based on various criteria, such as statistically significant AR and MA estimated coefficients at the 5 per cent level, absence of serial correlation, and optimisation of the Akaike Information Criterion (AIC) and Schwarz Criterion (SC). Diagnostic checking involves residual analysis to ensure that the estimated model has independent and identically distributed errors. When a satisfactory model has been selected, it is used in the third phase to forecast future values for total water demand and demand for water for agricultural, domestic and industrial use.

7.2 ESTIMATES OF THE ARIMA MODEL

7.2.1 Using the Best Fitting Model during the Period 1975-2005

The best fitting ARIMA models are estimated separately for the water demand series from 1975 to 2000 and the tests indicate that the ARIMA (3,1,1), (3,1,1), (1,1,1) and (1,2,1) models perform well. The coefficients are all significant, and they satisfy the stationarity and invertibility conditions. Each model has the highest adjusted R^2 and the lowest AIC and SIC values of six candidate models (for more information see Tables (A7.29) to (A7.48) and figures (A7.10) to (A7.37) in the appendices).The correlogram and unit root tests of the series before and, if necessary, after differencing are examined for stationarity. After empirical examination, the most appropriate models for total water demand and demand for water for agricultural , domestic and industrial use are determined as ARIMA (3,1,1), ARIMA (3,1,1), ARIMA (1,1,1) and ARIMA (1,2,1) respectively. Using the best fitting model for total water demand, demand for water for agriculture, domestic and industrial use are calculated in tables (7.6), (7. 7), (7. 8) and (7. 9).

$$\Delta \ln W_t = \alpha_0 + \alpha_1 \Delta \ln W_{t-1} + \alpha_2 \Delta \ln W_{t-2} + \alpha_3 \Delta \ln W_{t-3} + e_t - \beta_1 e_{t-1} \quad \text{ARIMA (3,1,1)}$$

$$\Delta \ln W_{A_t} = \alpha_0 + \alpha_1 \Delta \ln W_{A_{t-1}} + \alpha_2 \Delta \ln W_{A_{t-2}} + \alpha_3 \Delta \ln W_{A_{t-3}} + e_t - \beta_1 e_{t-1} \quad \text{ARIMA(3,1,1)}$$

$$\Delta \ln W_{D_t} = \alpha_0 + \alpha_1 \Delta \ln W_{D_{t-1}} + e_t - \beta_1 e_{t-1} \quad \text{ARIMA (1,1,1)}$$

$$\Delta\Delta \ln W_{I_t} = \alpha_0 + \alpha_1 \Delta\Delta \ln W_{i_{t-1}} + e_t - \beta_1 e_{t-1} \quad \text{ARIMA (1,2,1)}$$

Table (7.6): $d \ln W$ (1975-2005): Comparison of alternative models

	$\overline{R}^2$	AIC	SC	SIG	STAT	INV
ARIMA(3,1,1)	0.63	-2.32	-2.08	All sign	$\sum \alpha < 1$	$\sum \beta < 1$
ARIMA(3,1,2)	0.45	-1.87	-1.58	2 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARIMA(5,1,1)	0.60	-2.18	-1.84	4 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARIMA(4,1,1)	0.31	-1.95	-1.56	2 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARIMA(2,1,1)	0.25	-1.66	-1.47	2 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARIMA(1,1,2)	0.30	-1.58	-1.59	All sign	$\sum \alpha < 1$	$\sum \beta < 1$

Notes: $\overline{R}^2$ is Adjusted R-squared, AIC is Akaike info criterion, SC is Schwarz criterion, SIG is Significant and STAT is Stationary i.e. $\sum \alpha < 1$, INV is Invertibility i.e. $\sum \beta < 1$

Table (7.7): $d \ln W_A$ (1975-2005): Comparison of alternative models

	$\overline{R}^2$	AIC	SC	SIG	STAT	INV
ARIMA(3,1,1)	0.42	-1.52	-1.30	All sign	$\sum \alpha < 1$	$\sum \beta < 1$
ARIMA(3,1,0)	0.20	-1.25	-1.05	3 insign	$\sum \alpha < 1$	………
ARIMA(4,1,1)	0.64	-1.95	-1.66	3 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARIMA(1,1,0)	0.05	-1.22	-1.13	one insign	$\sum \alpha < 1$	………
ARIMA(1,1,1)	0.09	-1.23	-1.09	2 insign	$\sum \alpha < 1$	$\sum \beta < 1$
ARIMA(2,1,1)	0.19	-1.28	-1.09	3 insign	$\sum \alpha < 1$	$\sum \beta < 1$

Table (7.8): $d\ln W_D$ (1975-2005): Comparison of alternative models

	$\bar{R}^2$	AIC	SC	SIG	STAT	INV
ARIMA(1,1,1)	0.50	-2.23	-2.08	All sign	$\sum\alpha<1$	$\sum\beta<1$
ARIMA(1,1,2)	0.07	-2.17	-1.98	One insign	$\sum\alpha<1$	$\sum\beta<1$
ARIMA(2,1,2)	0.16	-2.22	-1.98	2 insign	$\sum\alpha<1$	$\sum\beta<1$
ARIMA(3,1,2)	0.12	-2.11	-1.82	3 insign	$\sum\alpha<1$	$\sum\beta<1$
ARIMA(5,1,1)	-0.08	-1.80	-1.49	4 insign	$\sum\alpha<1$	$\sum\beta<1$
ARIMA(4,1,0)	-0.18	-1.84	-1.60	4 insign	$\sum\alpha<1$	....

Table (7.9): $dd\ln W_I$ (1975-2005): Comparison of alternative models

	$\bar{R}^2$	AIC	SC	SIG	STAT	INV
ARIMA(1,2,1)	0.48	-2.83	-2.69	One insign	$\sum\alpha<1$	$\sum\beta<1$
ARIMA(1,2,0)	-0.02	-2.19	-2.09	One insign	$\sum\alpha<1$	....
ARIMA(2,2,1)	-0.02	-2.09	-1.90	2 insign	$\sum\alpha<1$	$\sum\beta<1$
ARIMA(3,2,1)	-0.04	-1.99	-1.75	3 insign	$\sum\alpha<1$	$\sum\beta<1$
ARIMA(4,2,1)	-0.06	-1.90	-1.61	4 insign	$\sum\alpha<1$	$\sum\beta<1$
ARIMA(1,2,2)	0.45	-2.75	-2.56	3 insign	$\sum\alpha<1$	$\sum\beta<1$

Since the specific ARIMA models that adequately describe total water demand and demand for water for agriculture, domestic and industry use are given above, the fitted models used for forecasting water demand for the four categories are given as follows:

Total water demand (1975-2005)

$$\Delta \ln W_t = 0.11 + 1.12\Delta \ln W_{t-1} + 0.55\Delta \ln W_{t-2} - 083\Delta \ln W_{t-3} + e_t + 1.59e_{t-1}$$

t- values (2.86) (6.29) (2.26) (4.78) (4.22)

$\overline{R}^2 = 0.63$ SC = -2.08 AIC = -2.32

Demand for water for agriculture (1975-2005)

$$\Delta \ln W_{At} = 0.05 + 0.89\Delta \ln W_{A_{t-1}} + 0.39\Delta \ln W_{A_{t-2}} - 0.45\Delta \ln W_{A_{t-3}} + e_t + 0.99e_{t-1}$$

t- values (3.399) (4.71) (2.44) (2.59) (9.70)

$\overline{R}^2 = 0.42$ SC = 1.30 AIC = 1.52

Demand for water for domestic use (1975-2005)

$$\Delta \ln W_{Dt} = 0.05 + 0.77\Delta \ln W_{D_{t-1}} + e_t + 0.96e_{t-1}$$

t- values (5.65) (7.76) (26.54)

$\overline{R}^2 = 0.50$ SC = -2.08 AIC = -2.23

Demand for water for industry (1975-2005)

$$\Delta\Delta \ln W_{It} = -0.002 + 0.55\Delta\Delta \ln W_{i_{t-1}} + e_t + 1.45e_{t-1}$$

t- values (0.29) (3.27) (6.62)

$\overline{R}^2 = 0.48$ SC = -2.69 AIC = -2.83

Tests for white noise residuals

Having used the ARIMA (3,1,1), (3,1,1), (1,1,1) and (1,2,1) models for total water demand, demand for water for agricultural, domestic and industrial use respectively, it is necessary to use different tests to determine if the residuals are white noise. These tests are: first, check the residual line graph; second, check the size of the differences between the fitted and actual values; third, check the residual correlogram for ARIMA (3,1,1) if white noise; fourth, check the test for autocorrelation in the residuals using the Serial Correlation Lagrange Multiplier test (LM); fifth, check the normality of the residuals ; finally, check if the series is stationary by using the unit root test. The key test is to determine whether the estimated residuals from the ARIMA (3,1,1), (3,1,1), (1,1,1) and (1,2,1) models are white noise (for more information see Figures (A7,1) to (A7,8) and Tables (A7.2), (A7.3), (A7.9), (A7.10), (A7.16), (A7.17), (A7.23) and (A7,24) in the appendices).

7.2.2 Magnitude of Forecasting Errors from 2001-2005

With the ex post forecast observations being demand for water for five years (2001-2005), Table (7.10) presents the root mean squared error (RMSE) forecast accuracy measure of the ARIMA models for total water demand, demand for water for agricultural, domestic and industrial use, the mean absolute percentage error (MAPE) of the ARIMA model in both static and dynamic forecasts. However, the static ARIMA model forecasts were better than the dynamic ARIMA model forecasts. These results suggest that the ARIMA (3,1,1), (3,1,1), (1,1,1) and (1,2,1) models perform better in forecasting total water demand, demand for water for agricultural, domestic and industrial use respectively.

Table (7.10): Root Mean Squared Error (RMSE) Ex post Forecasts of the Logarithm of Demand for Water, 2001-2005: Forecasting comparison between first and second best alternative models

	RMSE		
	ARIMA	Static	Dynamic
$\ln W$	(3,1,1)	0.01	0.04
	(3,1,2)	0.03	0.06
$\ln W_A$	(3,1,1)	0.02	0.07
	(1,1,1)	0.05	0.07
$\ln W_D$	(1,1,1)	0.04	0.06
	(1,1,2)	0.18	0.05
$\ln W_I$	(1,2,1)	0.02	0.01
	(1,2,0)	0.2	0.02

Data sources: see tables and figures (A7, 29) to (A7.44) in the appendices.
Second best alternative models from tables (7.6) to (7.9).

Table (7.10) shows the RMSE for the fitted ARIMA (3,1,1), (3,1,1), (1,1,1) and (1,2,1) models against the second best (3,1,2), (1,1,1), (1,1,2) and (1,2,0) models. It suggests that the models which we tested for forecasting are more accurate than others during the period 2001-2005.

The fitted values, which are interpreted as the forecasts for the next five years, are close to the actual values for total water demand, demand for water for agricultural, domestic and industrial use using the ARIMA models, as shown in tables (A7.29) to (A7.44) and figures from (A7.13) to (A7.39) in the appendices.

7.3 THE RESULTS OF FORECASTING WATER DEMAND FROM 2006-2020

A forecast is a conditional statement about the future. It is about what is expected to happen if various assumptions turn out to be valid. There are objective and subjective components involved in forecasting. The objective component consists of explaining past levels and patterns, while the subjective component is the application of the resultant knowledge to the future (Boland, 1985; Prasifka, 1988).

There are several terms which are similar, but do not have exactly the same meaning as the word 'forecast'. Prediction is used in more general ways than 'forecast'. Prediction is a statement about the future, whether conditional or not. So, forecasts may be regarded as predictions, but not all predictions are forecasts. Many forecasts rely on a set of assumptions which includes the continuation of at least some past trends and /or relationships. Such forecasts are called projections (Boland, 1985) in terms of the forecasting method employed.

However, the accuracy of the forecast depends on:

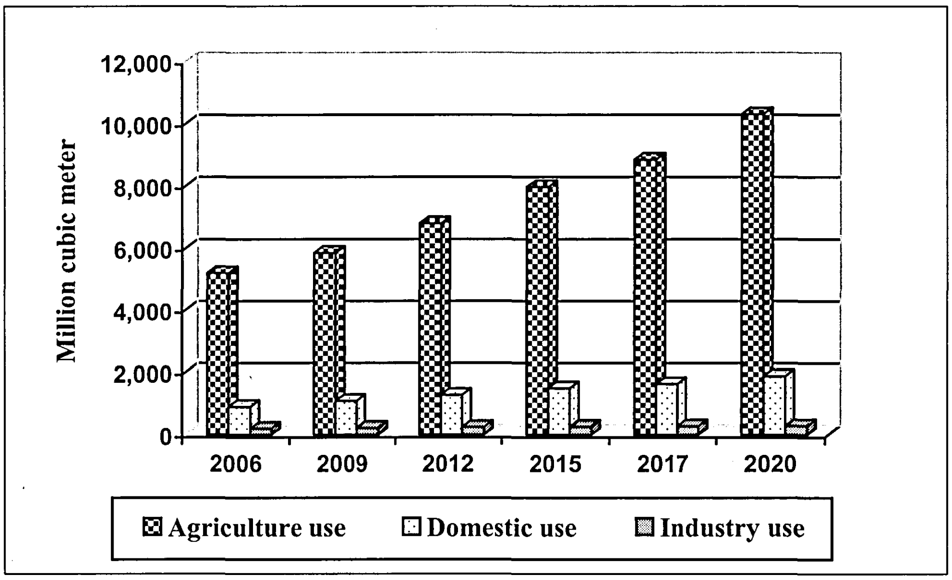
The specification of the model (a good specification of a model should generate a good forecast), the accuracy of the estimates of the parameters of the model and the goodness of fit of the model (Darnell, 1994).

Low RMSE for forecasting purposes is a desirable measure of forecasting fit. The RMSE for forecasting computed over the forecast range provides a measure of the ability of the model to forecast.

For estimation of prospective water consumption the equations for total water demand and demand for agricultural, domestic and industrial use have been applied. For more information see tables from (A7.46) to (A7.53) and figures

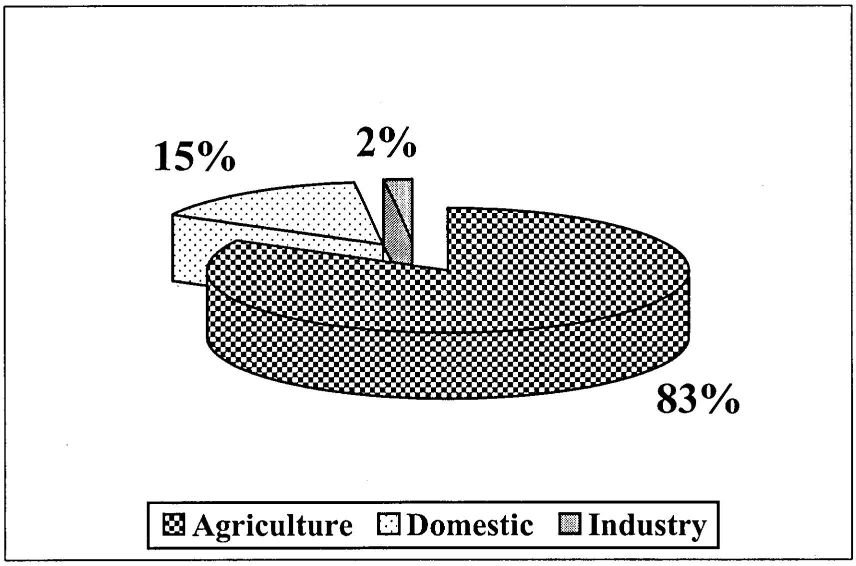
(A7.37) to (A7.39) in the appendices. By viewing table (7.11) which shows the estimations of prospective water consumption during the period 2006-2020, the following can be noticed: the prospective estimations of water consumption for all possible purposes indicate total water consumption increasing from 6293.89 million cubic metres in 2006 to 12473.20 million cubic metres in 2020 with an average compound annual growth rate of 4.97%. In 2020 it is expected that the increase will be 98% of the water consumption in 2006. i.e. total water demand will almost double in this period.

Figure (7.2): Water Demands in Libya, 2006-2020



Data source: table (7.11)

Figure (7.3): Water demand in 2020



Data source: table (7.11)

Agriculture will continue to be the major water consumer; it becomes the biggest consumer of water as shown in table (7.11) and figure (7.3). It represents about 83% of the estimated water consumption in 2020 and despite the use of pressurized irrigation techniques in practically all farming areas, application rates are still among the highest in the world. Actually, this large increase in water consumption for agricultural use will affect the water reserve. Therefore, the way to guide water consumption in the agriculture sector has to be considered.

This is mainly due to the unsuitable climatic and soil conditions. Different scenarios can be presented for the estimation of future water demand by the agricultural sector. A reasonable one is that shown in table (7.11).

Table (7.11): Water Demands by Different Users in Libya 2006-2020

Year	Water Demand (Million Cubic Metres)			
	Agricultural Use	**Domestic Use**	**Industrial Use**	**Total Demand**
2006	**5204.43**	**895.75**	**193.71**	**6293.89**
2007	5384.29	958.96	202.30	6545.55
2008	5601.55	1022.69	210.70	6834.94
2009	5854.41	1084.98	218.69	7158.08
2010	**6171.39**	**1147.69**	**227.24**	**7546.32**
2011	6194.89	1204.19	233.08	7632.16
2012	6803.48	1275.93	241.08	8320.49
2013	7172.95	1342.17	247.79	8762.91
2014	7564.41	1410.49	254.07	9228.97
2015	**7975.77**	**1494.92**	**259.85**	**9730.54**
2016	8405.78	1555.31	265.12	10226.21
2017	8853.87	1631.83	269.82	10755.52
2018	9320.22	1711.56	273.93	11305.71
2019	9805.61	1794.76	277.41	11877.78
2020	**10311.30**	**1881.66**	**280.24**	**12473.20**

Data source: tables from (A7.46) to (A7.53) in the appendices.

Efficiency of the applied irrigation systems is in the order of 40 to 60% for surface irrigation, 60 to 75% for sprinkler irrigation and >80% for localized (micro) irrigation. Efficiency is expected to be further improved by expansion of localized irrigation. In fact, a few factories producing micro-irrigation equipment are already in operation in Libya. Agriculture consumes nearly 87% of useful land. It accounts for 7.8% of the GDP and employs nearly 12% of the workforce (National Environmental Authority, 2002: 67). This contribution would decrease because of water scarcity which characterizes Libya, but the Libyan government counts on the project of the large artificial river for at least "preserving the areas which are under irrigation at the moment, and perhaps, extend them". Water demand for irrigation is estimated at a volume of 4300 million cubic metres in 2005, which is necessary to irrigate 450,000 hectares, this volume would increase to 6300 million cubic metres (650,000 hectares) by 2020(Hajjaji, 2001).

The prospective water consumption for domestic purposes will increase from 895.75 million cubic metres in 2006 to 1881.66 million cubic metres in 2020 with an average compound annual growth rate of 5.4% in 2020. That can be explained by the expected increase of population and their needs for water. It is worth mentioning here that the consumed water quantity in the northern regions will depend, in addition to the groundwater, on waters obtained from desalination plants.

The water consumption of industrial use will increase. The water quantity to be consumed for industrial purposes in 2020 is expected to be about 2% of the total water consumption. Using water for industrial purposes will rely mainly on desalinated water. In spite of the positive relation between industrial expansion and water demand, and the expected increase of water consumption during the period 2006-2020, the consumed quantity for industrial purposes is considered small, if compared with water quantities consumed for other purposes.

Industry consumes the least water of all sectors, with a current share of about 2%. A large number of industries depend on private sources for water supply, including desalination of seawater, as in the case of chemical, petrochemical, steel, textile and other industries.

Industry uses 2% of the Libyan water resource, increasing water demand to 280.24 million cubic metres in 2020.

7.4 CONCLUSIONS

This chapter has discussed the Box-Jenkins approach to modelling ARIMA processes.

The use of such procedures, particularly tests for unit roots, improves the validity of using the ARIMA models for forecasting and allows the forecaster to make informed judgments at each step as the results are presented by the statistical packages. The Dickey-Fuller test was used to test the stationarity of each individual variable. The test ADF statistic of all variables clearly does not reject the null hypothesis; this means we are 95% confident that all series follow a difference stationarity process. Overall, this chapter shows that by comparing the root mean squared errors, lower post-sample forecast errors were obtained when time series methods, such as the Box-Jenkins ARIMA models, were used.

One major conclusion has been that the way that the data are made stationary is the most important factor determining post-sample forecasting accuracies. Estimation of water consumption for all possible purposes indicates that total water consumption is increasing from 6293.89 million cubic meters in 2006 to 12473.20 million cubic meters in 2020 with an average compound annual growth rate of 4.97%. In 2020 it is expected that the increase will be 98% of the water consumption in 2006 i.e. total water demand will almost double in this period.

The next step is to estimate the elasticity of the variables for all equations by using the Engle-Granger two-step procedure. This will be the subject of the next chapter.

CHAPTER EIGHT

ESTIMATION OF THE VARIABLE ELASTICITIES USING THE ENGLE-GRANGER TWO-STEP MODEL

8.0 INTRODUCTION

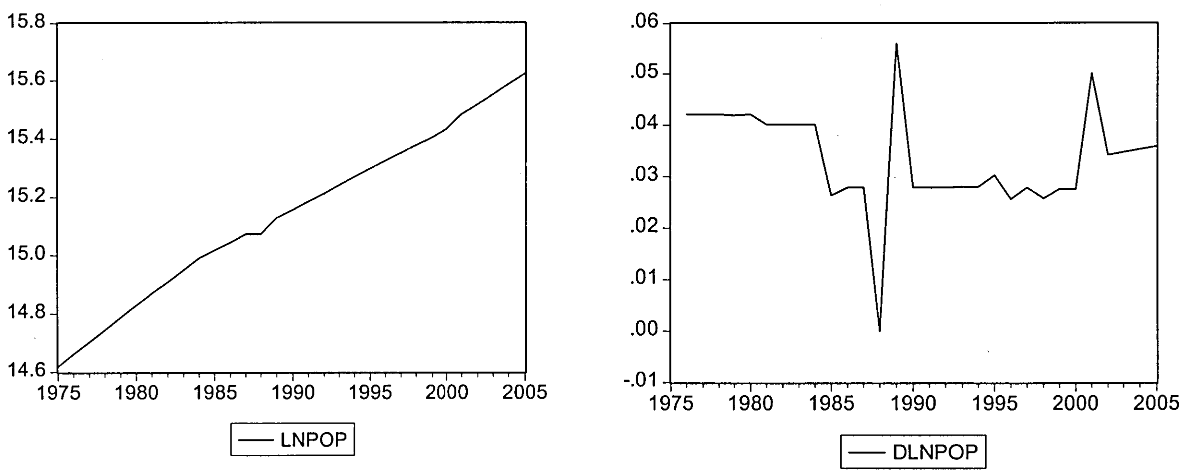
The main objective of this chapter focuses on the determinants of elasticities of water demand and examines the effect of price, income, population and temperature on water demand in Libya in the short-run and long-run. To achieve these goals, unit root tests for all variables will be used to check the stationarity and order of integration of each individual variable in section 8.1. The first step is to estimate the long-run cointegration relationships between the variables and the second step in this procedure is to estimate the error correction model (ECM) for each behavioural equation of the model. The results for the short-run dynamic relationship will be examined in section 8.2. Section 8.3 determines elasticity estimates for all variables in the long and short-run and discusses the results. Economic theory suggests the sign and the size of the coefficients of the explanatory variables. Also, statistical criteria will be used in selecting the best equation to explain the short-run dynamic relationship. Section 8.4 is allocated to the conclusions.

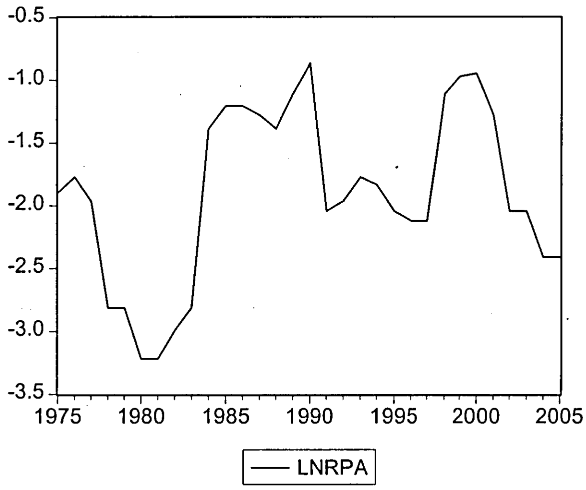
8.1 TESTING FOR STATIONARITY

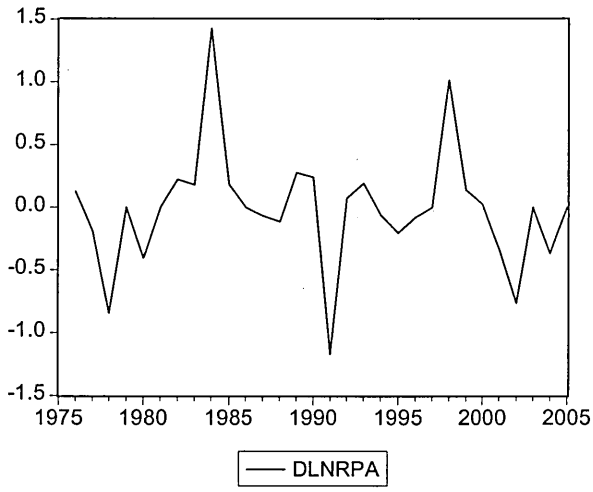
8.1.1 Graphs of Variables

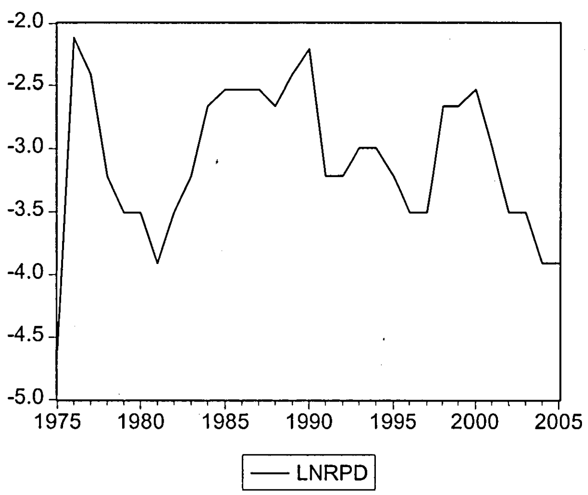
The first method which can be used to check the stationarity of the variables is to graph the series of these variables which are shown in figure (8.1) (in levels and in first differences) except $\ln W, \ln W_A, \ln W_D$ and $\ln W_I$ which are given in the previous chapter.

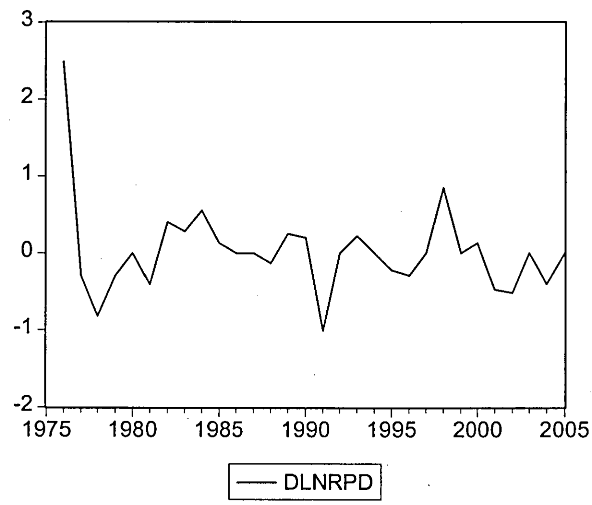
Figure (8.1): Graphs of the Explanatory Variables (in level and in first differences)

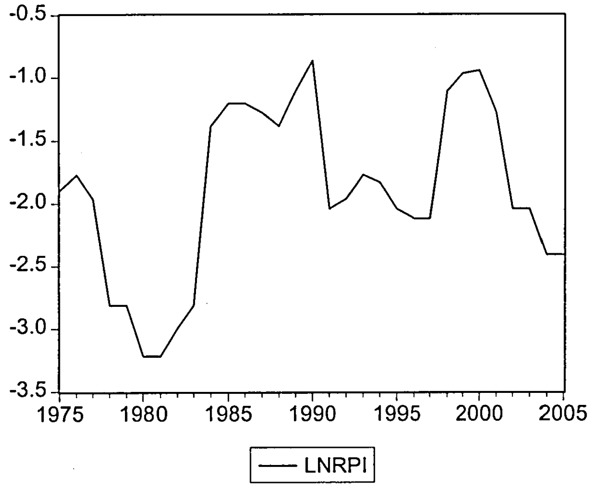


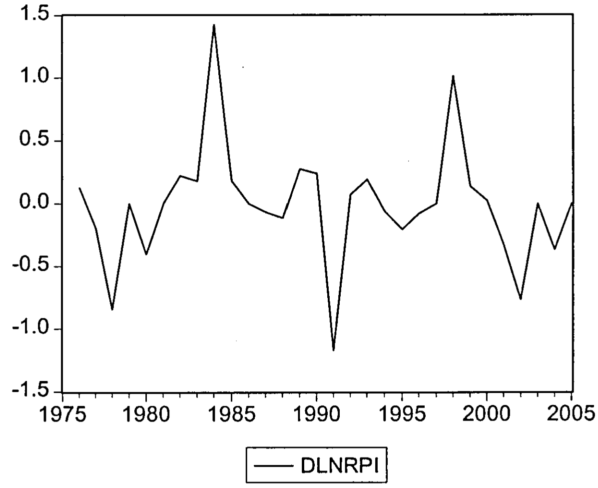

-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
1975
1980
1985
1990
1995
2000
2005
LNRPA

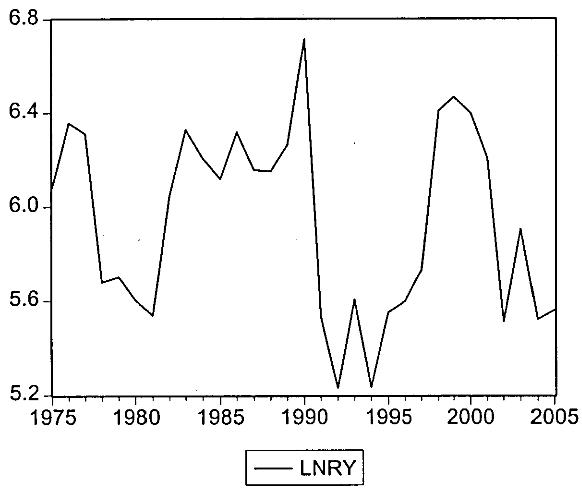

1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
1975
1980
1985
1990
1995
2000
2005
DLNRPA

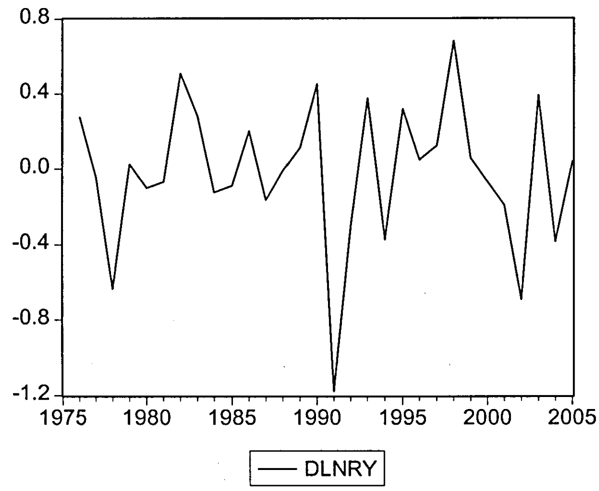

-2.0
-2.5
-3.0
-3.5
-4.0
-4.5
-5.0
1975
1980
1985
1990
1995
2000
2005
LNRPD

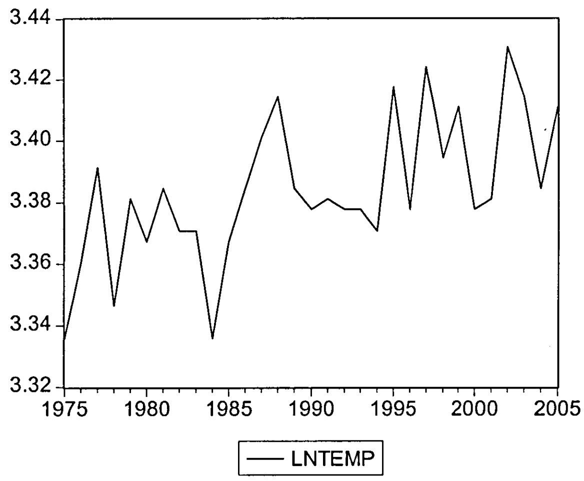

3
2
1
0
-1
-2
1975
1980
1985
1990
1995
2000
2005
DLNRPD

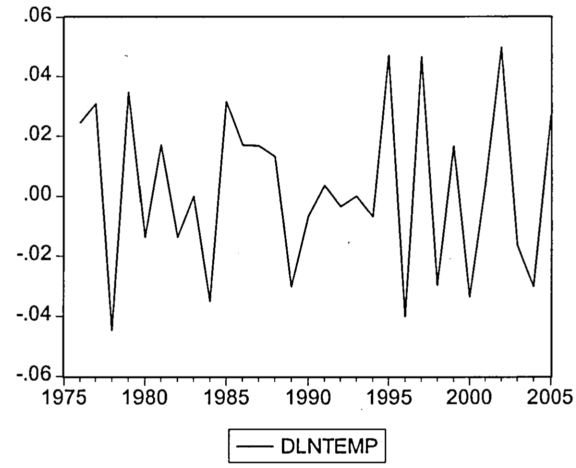

-0.5
-1.0
-1.5
-2.0
-2.5
-3.0
-3.5
1975 1980 1985 1990 1995 2000 2005
LNRPI


1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
1975 1980 1985 1990 1995 2000 2005
DLNRPI


6.8
6.4
6.0
5.6
5.2
1975 1980 1985 1990 1995 2000 2005
LNRY


0.8
0.4
0.0
-0.4
-0.8
-1.2
1975 1980 1985 1990 1995 2000 2005
DLNRY





According to the above graphs, the results appear to indicate that all variables are stationary in first differences. Hence, the variables appear to be integrated of order one. For a more rigorous approach, however, the unit root test is used in the next section.

8.1.2 Unit Root Tests for Model Variables

All the data are annual and are for calendar years. Econometricians suggest that the first step in any empirical analysis should be to examine each of the variables individually to check their order of integration (Holden and Thompson; 1992:10). The Dickey-Fuller test is used to test for unit roots for each variable. The essence of the Dickey-Fuller test [Fuller (1976) and Dickey and Fuller (1979), (1981) is that rejection of the null hypothesis implies stationarity. This requires negative and significant test statistics. Although the test statistics are calculated as t-ratios in the Dickey-Fuller test (DF) and Augmented Dickey-

Fuller (ADF) regressions, the non-stationarity implies that they do not have standard t-distributions and so the tables of Mackinnon (1991) are used. ADF test statistics have been calculated for the model variables, both in their levels and in first differences. The unit root tests have been carried out for each variable by applying (8-1) or (8-2) which are represented below, and testing whether $\phi = 0$

$$\Delta Y_t = \alpha + \phi Y_{t-1} + u_t \tag{8-1}$$

$$\Delta Y_t = \alpha + \phi Y_{t-1} + \gamma t + u_t \tag{8-2}$$

Where ΔY_t is the first difference of Y_t

Table (8.1) presents the results of these tests for the behavioural equation variables in levels and in their first and second differences. All variables are expressed in natural logarithm form. Income and price are estimated in real terms (RY), (RP_A),(RP_D) and (RP_I). The reasons for using natural logarithms are that coefficients can be interpreted as constant elasticities, they can help to reduce the problem of heteroscedasticity , and reduce the non linearity of the relationship.

The ADF test statistic is calculated with and without a time trend. The ADF test is applied with one lagged ΔY_t term. This was sufficient to remove any auto-correlation. The values of these test statistics with 5 per cent critical values, as tabulated in Mackinnon (1991), are included in table (8.1) The results indicate that none of the variables is stationary in its level. However, ADF test statistics for the variables in their first differences are stationary implying that each variable is integrated of order one (except $\ln W_I$ whish is integrated of order two).

The results are summarized in table (8.1). The table also shows that for all the levels series we do not reject the null hypothesis of a unit root.

Table (8.1): Results of Unit Root Tests for Model Variables

	Level		**First Difference**	**Second Difference**	
	With trend	Without trend	Without trend	Without trend	
	ADF	ADF	ADF	ADF	Conclusion
$\ln W$	-0.71	-2.58	-4.51	_	I(1)
$\ln W_A$	-0.78	-2.84	-3..77	_	I(1)
$\ln W_D$	-2.19	-1.74	-3.52	_	I(1)
$\ln W_I$	-2.59	-2.91	-1.39	-3.72	I(2)
$\ln RP_A$	-2.36	-2.23	-3.34		I(1)
$\ln RP_I$	-2.36	-2.23	-3.34	_	I(1)
$\ln RP_D$	-2.56	-2.60	-4.83	_	I(1)
$\ln pop$	-2.6	-1.58	-5.14	_	I(1)
$\ln RY$	-2.75	-2.77	-4.40	_	I(1)
$\ln temp$	-2.04	-2.75	-5.67	_	I(1)

5% critical values:
Without time trend ADF = -2.97
With time trend ADF = -3.57

8.2 ENGLE-GRANGER TWO-STEP PROCEDURE

In the Engle-Granger two-step (EG2S) procedure, variables entering the co-integrating vector are tested for integration of the same order, in particular order one I(1). The first step is to estimate the long-run static model of the I(1) variables and obtain the residual. If this residual, which is the linear combination of the variables, is stationary, then the variables are said to be cointegrated, that is, they do have a long-run relationship. The second step in this procedure is to estimate the error correction model (ECM). That is, the first difference of the dependent variable is regressed on the first differences of the explanatory variables with their appropriate lags, and the first lag of the residual obtained in the first step

8.2.1 Cointegration Tests: Long-Run Equilibrium

The cointegration test suggested by Engle and Granger is based on the estimated residuals of the cointegration regression. The estimated residuals are then tested for the existence of a unit root in the autoregressive representation.

If these residuals are found to be stationary, then the variables are cointegrated. However, before testing for cointegration, a unit root test is required to ensure that the variables under study are nonstationary I(1). The cointegration test is only applicable if the variables are of the same order I(1). Thus, we employ the Augmented Dickey- Fuller (ADF)(Dickey and Fuller,1979,1981) unit root test.

The results in step one indicate that all variables in equations (8.3) and (8.4) are integrated of the same order I (1) except equation (8.5). Although the unit root test suggest that $In W_I$ is an I(2) variable, the cointegration test suggests we can treat $\ln W_I$ as an I(1) variable.

$$InW_A = \alpha_A + \beta_1 InP_A + \theta_1 Inpop + \gamma_1 InY + \psi_1 Intemp + u_A \quad \text{(8-3)}$$

$$InW_D = \alpha_D + \beta_2 InP_D + \theta_2 Inpop + \gamma_2 InY + \psi_2 Intemp + u_D \quad \text{(8-4)}$$

$$InW_I = \alpha_I + \beta_3 InP_I + \theta_3 Inpop + \gamma_3 InY + \psi_3 Intemp + u_I \quad \text{(8-5)}$$

The estimation of coefficients of these equations are given in table (8.3)

We save the estimated residuals of the static models in equations (8.3), (8.4) and (8.5) and test them for stationarity. The results are in table (8.2).

Table (8. 2): Results of Unit Root Tests for Stationarity of the Estimated Residuals

Variable		$\ln W_A$ **With Four Lags***	$\ln W_D$ **With One Lag***	$\ln W_I$ **With One Lag***
$\hat{u}_t$		-2.43	-2.88	-2.25
Critical Values	**5%**	-1.95	-1.95	-1.95
	10%	-1.62	-1.62	-1.62

Data source: tables (A8.1) to (A8.6) in appendices.

*we have chosen these lags to remove any auto-correlation

As shown in table (8.2) the test ADF statistic of all estimated residuals clearly rejects the null hypothesis of no cointegration at all conventional significance levels at the critical values 5% and 10%. This means that a long-run equilibrium relationship has been established. The next step is to estimate the short-run equilibrium relationship.

8.2.2 Step Two: Estimation of the Error Correction Model (ECM)

Error correction models are based on the behavioural assumption that two or more time series exhibit an equilibrium relationship that determines both short- and long-run behaviour[1]. Scientists in all empirical fields are increasingly positing theories of dynamics that are consistent with this behavioural model[2].

[1] This long-run equilibrium is assumed in virtually all dynamic models involving levels data but is trivial in the stationary case. The equilibrium can be modelled in many ways when the data are

Analysts have argued that presidential approval and economic conditions are tied together such that positive support cannot be maintained over periods of recession (Ostrom and Smith 1992; Clarke and Stewart 1994).

Others have argued that relationships are conditional upon a long-run equilibrium: cooperative overtures of one country cannot continue when a neighbour is repeatedly antagonistic (Rajmaira and Ward 1990). Still others contend that policy sentiment is tied in the long run to economic conditions and government spending (Durr 1993; Wlezien 1996, 1995), that taxes and benefits are tied by "actuarial soundness" (Mebane 1994), that economic evaluations are linked to economic conditions (Krause 1997), and that political forces and seat distributions in legislatures are linked in the long run to form an equilibrium relationship (Simon et al. 1991). Finally, party support, some argue, is sustained by positive political and economic experience (MacKuen et al. 1998; Green et al. 1998). If these kinds of long-run relationships describe behaviour, the ECM presents a nice fit with theory.

If the series are found to be nonstationary I(1) and cointegrated, Engle and Granger (1987) suggest including an equivalent Error Correction Model (ECM) to re-parameterise the model . The ECM combines both short- run properties of economic relationships in first-difference form and long-run information provided by the data in level form. Furthermore, the ECM is considered a

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stationary, including autoregressive distributed lag models, generalized error correction models, and other dynamic regressions. See Beck (1991) and Banerjee et al. (1993) for a discussion.

[2] For a discussion of ECMs in political science, see Ostrom and Smith (1992) or Durr (1993). For an introduction to ECMs more generally, see Banerjee et al. (1993).

dynamic process because it involves lags of dependent variables and it thus captures short-run adjustments to changes, in particular adjustments to past diseqilibrium and contemporaneous changes in the explanatory variables. The ECM also enables researchers to estimate the speed of adjustment back to the long-run equilibrium among the variables. In this regard, Engle and Granger (1987) warn that failure to include the lagged residual of the cointegrating equation in a (short-run) model in difference form results in a misspecified relationship because the long-run properties of the model are ignored.

Thus it can be concluded that if variables are found to be cointegrated, there must exist an associated Error Correction Mechanism (ECM) (Engle and Granger, 1987).

8.2.2.1 Application of the Error Correction Model for Water Demand for Agricultural, Domestic and Industrial Use

Having estimated the long-run relationships between the variables in each equation, the short run dynamic structure of the model is also needed.

This section is divided into three sub-sections: estimating, discussing, and presenting the ECM for the three equations included in the model.

Table (8.3): Variable Elasticities: Long-Run and Short -Run Analysis

Dependent Variables	Coefficients	Stage One Long Run Elasticities	Stage Two Short Run Elasticities
$\ln W_A$	β_1	-0.27	-0.03
	θ_1	2.83	0.20
	γ_1	0.18	0.01
	ψ_1	0.07	0.42
$\ln W_D$	β_2	-0.14	-0.04
	θ_2	1.70	0.39
	γ_2	0.15	0.06
	ψ_2	1.27	0.83
$\ln W_I$	β_3	-0.49	-0.02
	θ_3	4.99	0.43
	γ_3	0.34	0.05
	ψ_3	2.76	0.21

Data source: tables from (A8, 7) to (A8, 9) in the appendices.

β = Price coefficient
θ = Population coefficient,
γ = Income coefficient and
ψ = Temperature coefficient

- **ECM for water demand for agriculture**

$$\Delta InW_A = \alpha_A + \beta_1 \Delta InRP_A + \theta_1 \Delta Inpop + \gamma_1 \Delta InRY + \psi_1 \Delta Intemp - (1-\delta_1)\hat{e}_{t-1} + u_A \quad (8.6)$$

$$\Delta InW_A = 0.11 - 0.03\Delta InRP_A + 0.20\Delta Inpop + 0.01\Delta InRY + 0.42\Delta Intemp - 0.26\hat{e}_{t-1} + u_A \quad (8.7)$$

t- value (4.13) (-2.36) (10.41) (0.97) (0.41) (-2.43)

DW = 2.13 R^2 = 0.92

- **ECM for water demand for domestic use**

$$\Delta InW_D = \alpha_D + \beta_2 \Delta InP_D + \theta_2 \Delta Inpop + \gamma_2 \Delta InRY + \psi_2 \Delta Intemp - (1-\delta_2)\hat{e}_{t-1} + u_D \quad (8.8)$$

$$\Delta InW_D = 0.07 - 0.04\Delta InRP_D + 0.39\Delta Inpop + 0.06\Delta InRY + 0.83\Delta Intemp - 0.39\hat{e}_{t-1} + u_D \quad (8.9)$$

t- value (7.21) (-3.19) (18.87) (2.27) (1.17) (-2.82)

DW = 1.71 $R^2 = 0.96$

- **ECM for water demand for industry**

$$\Delta InW_I = \alpha_I + \beta_3 \Delta InRP_I + \theta_3 \Delta Inpop + \gamma_3 \Delta InRY + \psi_3 \Delta Intemp - (1-\delta)\hat{e}_{t-1} + u_I \quad (8.10)$$

$$\Delta InW_I = -0.03 - 0.019\Delta InRP_I + 0.43\Delta Inpop + 0.05\Delta InRY + 0.21\Delta Intemp - 0.02\hat{e}_{t-1} + u_I \quad (8.11)$$

t- value (-4.5) (-2.07) (8.77) (0.900) (0.36) (-0.02)

DW = 2.35 $R^2 = 0.89$

The short-run relationships for water demand for the agriculture, domestic and industry equations generally have significant coefficients at the 5% level and they are satisfactory models. Although the coefficient for $\ln RY$ has low t-values in two out of three cases.

The short run elasticities indicated in equations (8.7), (8. 9) and (8. 11) seem sensible. All variable elasticities are less than one except population which is greater than one in the long-run. Also, the price coefficients were negative; these elasticities indicate that water use is generally inelastic with respect to price, and suggest that there is an inverse relationship between water demand and price. Elasticity is very important especially in the field of water services. Providers are interested in how demand is affected by changes in price, population, income and temperature and also the reaction of demand when one of the variables changes. To determine the effect on the demand, we computed the price, population, income and temperature elasticities.

8.3 SUMMARY AND DISCUSSION OF THE RESULTS

- The 't' values of all the estimated coefficients indicate coefficients which are significantly different from zero in thirteen cases out of eighteen and all variables have the expected sign, according to economic theory. This indicates that the results are good and the model seems sensible to estimate elasticties for population, price, income and temperature.
- The unit root test on the lagged residuals from the cointegrating equations implies that the explanatory variables in the long-run equations are, in fact, cointegrated. This means that a long-run equilibrium relationship has been established.
- The short and long-run price elasticities are negative, suggesting that there is an inverse relationship between water demands and price. Also, these elasticities indicate that water use is generally inelastic with respect

to price. It is a similar result to those given by Griffin (1990), De Rooy (1974) and Moore (1963) in chapter two. Prices have significant effects for water demand for agricultural, domestic and industrial use. For example in the long-run, if the price increases by 10% the water demand for agricultural, domestic and industrial use will decrease by 2.7%, 1.4% and 4.9% respectively.

- The estimates of population elasticities show that in the short-run water demand is inelastic. A 10% increase in population will increase water demand for agricultural, domestic and industrial use by 2.0%, 3.9% and 4.3% respectively. While in the long run water demand for all purposes is highly elastic with respect to population. For example if the population increases by 10% the water demand for agriculture, domestic and industrial use will increase by around 28%, 17% and 49% respectively.
- The income elasticities are all positive in the short and long-run. This result agrees with Griffin (1990), Foster (1979) and Darr (1975) in chapter two. This result accords with demand theory, implying that water is a normal good, while a negative value indicates that a commodity is inferior. Income elasticities greater than unity characterise luxury goods where budget shares increase with income, while necessities, having elasticity values between zero and one, experience falls in their budget shares with increases in income. In our case, it is found that the elasticities are between zero and one, implying in the long-run that a 10% increase in real income would lead to a 1.8%, 1.5% and 3.4% increase in demand for agricultural, domestic and industrial use respectively.

- Water demand with respect to temperature is inelastic in the short run and elastic in the long-run in two cases (demand for water for domestic and industrial use). The temperature coefficients are insignificant in all three cases (demand for water for agricultural, domestic and industrial use).
- The estimation results suggest that, in the long-run, water demand for agricultural, domestic and industrial use is highly elastic for population and inelastic for price and income.
- The short-run elasticities are less than the long-run elasticities. Also all elasticities in the short run are less than one. This means that, water demand is inelastic in the short run.

Overall, the models seem well-specified and give sensible results consistent with economic theory.

8.4 CONCLUSIONS

In this chapter the model of Libyan water demand outlined in the previous chapter was estimated using the Engle-Granger two-step procedure. Two econometric techniques were applied. Unit root tests for all variables were used to check the stationarity and order of integration of each individual variable. The coefficient of the error correction term in all the error correction equations is significant in two out of three equations. This provides additional evidence of cointegration. Economic theory suggests the sign and the size of the explanatory variable coefficients in the long-run and these were satisfactory. The results in step one indicate that all variables are integrated of the same order I (1) except

InW_I , although the unit root test suggests that InW_I in the cointegration regression can be treated as an I(1) variable.

The test ADF statistic clearly rejects the null hypothesis of no cointegration at all conventional significance levels at critical values 5% and 10%. Elasticity estimates were derived and for all variables it was found that water demand is indeed highly sensitive to population increase, but less sensitive to price and income changes. For the most part, this result indicates that short-and long-run water consumption and economic activities are interrelated. The model estimates show that, for all sectors, water consumption varies strongly with population growth. Water demand with respect to population is inelastic in the short run and highly elastic in the long run. The next chapter focuses on the relationship between population growth and water consumption in the future.

CHAPTER NINE

THE RELATIONSHIP BETWEEN POPULATION GROWTH AND WATER CONSUMPTION IN THE FUTURE

9.0 INTRODUCTION

It became clear to us through the discussions of previous chapters that the high population growth in Libya was accompanied by a large increase of water consumption for agricultural purposes as well as domestic and industrial uses, which affected the water reserves in the water basins especially in the northern regions of the country. In this chapter the discussion about the relationship between population growth and future water consumption, particularly from 2006 to 2020, is continued.

In addition, the forecasting results of water demand which we have obtained in the previous chapters are undertaken and compared. Section 9.1 gives details about the future forecast of population which relies on the data published by the Secretariat of the General People's Committee of Planning, Economy & Commerce. Section 9.2 is concerned with the future forecast of water consumption. Section 9.3 discusses the relationship between population growth and water consumption to give general indications regarding the water quantities which may be consumed by a certain population for agricultural, domestic and industrial purposes. Finally, a conclusion to the above discussions is provided in section 9.4.

9.1 FORECASTS OF POPULATION

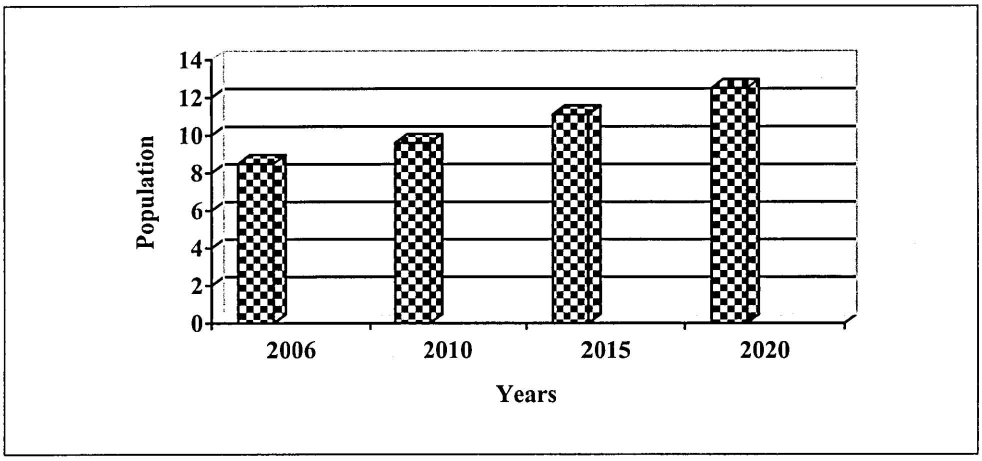
The problem of rapidly increasing population in Libya, which is more than 3% annually, is considered among the highest worldwide. The continuing population increase will be a major challenge for Libyan planners. According to the Secretariat of the General People's Committee of Planning the population projections indicate that population in Libya will exceed 12 million in 2020 (Table (9.1) and Figure (9.1)). More than 90% of them will live in urban areas. As urban areas grow, the demand for water resources is likely to grow because urban populations, on average, use more water for domestic and industrial purposes than rural populations. The Libyan case shows how the rapid growth of Tripoli and Benghazi, the country's two major cities, has led to the unsustainable pumping of a major aquifer. This has reduced water availability for local farmers, and resulted in the desiccation of a wetland of international importance. On the other hand, urbanisation can also present opportunities through economies of scale for more efficient and cost-effective water management. Alternatively, increasing population needs a rapid achievement of increasing agricultural, animal productions and food supply followed by intensification of agriculture. Also, it leads to settlement expansion with a loss of fertile lands. Economic and social interactions will, therefore, play an essentially vital role in determining the overall population needs for increasing amounts of water.

Table (9.1): Estimated Future Population 2006-2020 (Millions)

Year	2006	2010	2015	2020
Population	8.5	9.6	11.1	12.5

Data source: General Planning Council,(2006), Report of Libyan Economic and Social Indictors 2006. http://www.gpc.gov.ly/online/detailsnews.php.

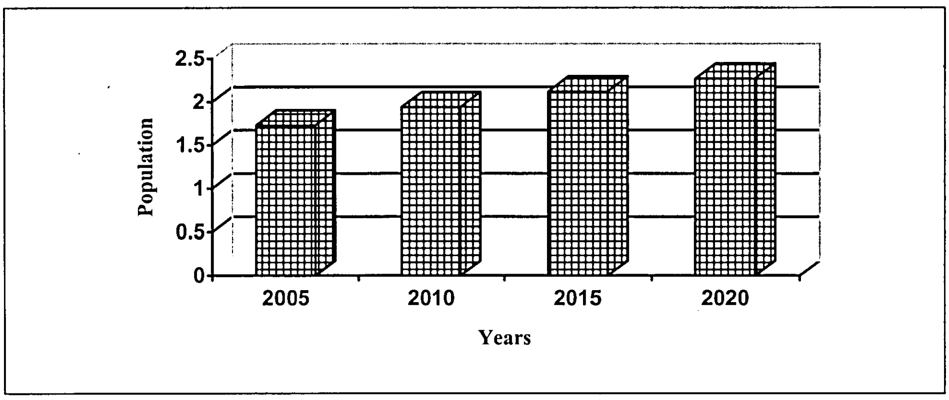
Figure (9.1): Estimated Future Population 2006-2020 (Millions)



Data sources: table (9.1)

For example in Jifara Plain, increasing population growth associated with limited natural resources (especially water resources) and high precipitation variabilities will accelerate, without any doubt, desertification in the future. Under the increasing population, the water deficit will increase in response to increasing water demands for domestic, industrial and agricultural purposes.

Figure (9.2): Population Growth of Tripoli City 2005-2020 (Millions)



Data source: Brauch, H. G. 2004. Urbanization and Natural Disasters in the Mediterranean: Population Growth and Climate Change in the 21stCentury. Available from: http://www. Proventionconsortium

Figure (9.2) shows the increase in Tripoli's population from 2005-2020. It can be noticed that the growth is sharp from 2005, the increasing population needs increasing water and food supply followed by intensification of the agriculture, concentrated use of fertilizers and pesticides. The destruction of vegetation has always proceeded from regions under human influence in response to the need for agricultural areas, roads, watering places, firewood, etc (Nasr, 1999: 27).

9.2 FORECASTS OF WATER CONSUMPTION

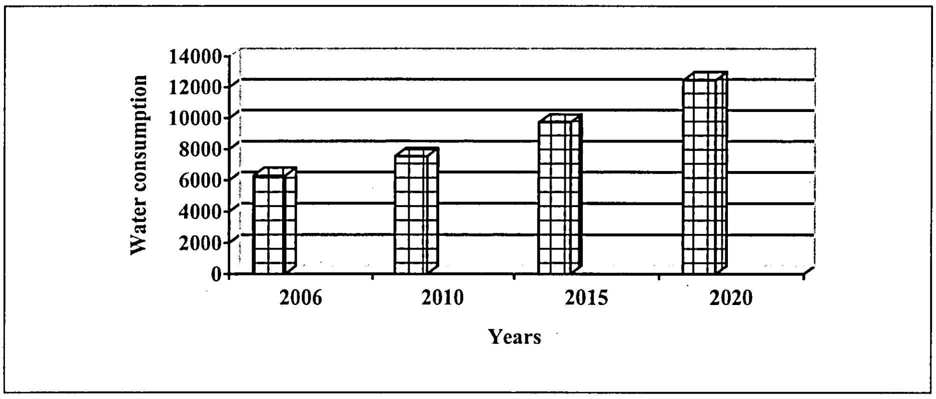
As we discussed in the previous chapter the biggest user of water in 2020 in Libya is agricultural (83%) followed by domestic use (15%) and industrial use (2%), see Table (7.11) and figure (7. 3) in the previous chapter. Large increases in water demand during the period 2006 to 2020 see (Table (9.2) and Figure (9.3)) with very little recharge from precipitation have strained Libya's groundwater resources resulting in declines of groundwater levels and its quality, especially on Mediterranean coastal areas where most of the agricultural, domestic and industrial activities are concentrated (Hirji and Ibrekk, 2001).

Table (9.2): Estimated Future Water Consumption 2006-2020 (Millions Cubic Metres)

Year	2006	2010	2015	2020
Water Consumption	6293.89	7546.32	9730.54	12473.20

Data sources: table (7.11)

Figure (9.3): Estimated Future Water Consumption 2006-2020 (Million Cubic Metres)



Data sources: table (9.2)

9.3 THE RELATIONSHIP BETWEEN POPULATION GROWTH AND WATER CONSUMPTION

Since the relationships between population dynamics and water resources have only recently begun to receive attention, additional research will be needed. Future research should be multidisciplinary, with research teams made up of hydrologists, engineers, ecologists, demographers, and other social scientists. Since population and water relationships are locally shaped, the perceptions and practices of local communities should actively be integrated into research activities.

Some specific topics for future research relevant to policy include: the relationship between land tenure and water rights; the impacts of changing population-water dynamics on households; estimates of the economics of water resources in different contexts; soil and water conservation techniques;

traditional water management strategies; comparative case studies on dam releases; and population-water relationships among populations living in or near protected areas and wetlands.

The growth of population has a marked impact on the water resources of Libya as a result of increasing demand for agricultural, domestic and industrial use (Table, 9.3) which suffered serious depletions and quality deterioration

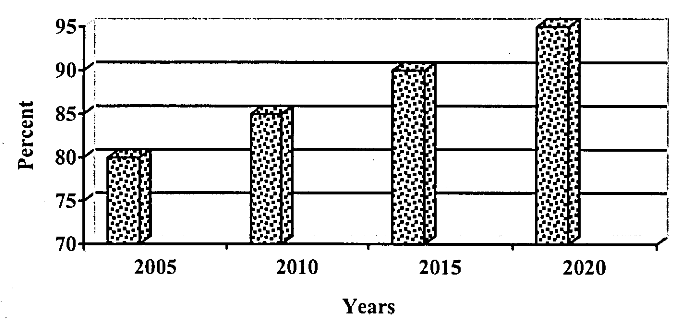
Table (9.3): Estimated Future Population and Water Consumption 2006-2020

Year	**2006**	**2010**	**2015**	**2020**
Population Million	8.5	9.6	11.1	12.5
Water Consumption Million Cubic Meters	6293.89	7546.32	9730.54	12473.20

Data source: Table (7.11) previous chapter

General Planning Council,(2006), Report of Libyan Economic and Social Indicators 2006. http://www.gpc.gov.ly/online/detailsnews.php.

Figure (9.4): Libyan Urbanization Level 2005-2020



Data source: National Information Authority of Libya, 2002

For estimation of future water consumption the equations (2-39), (2-40), (2-41) and (2-42) in chapter two have been applied. By viewing table (7.11) and (8.3) in the previous chapter, which shows the estimates of future water consumption during the period 2006-2020, the following can be noticed:

- A primary driver of change in Libya's direct and indirect water demand will be the change in population. Libya's population growth rate has increased rapidly over the past 30 years
- While population will be the primary factor driving overall water demand, urbanization of that population will also be important. Libya has had some of the world's fastest growing cities over the past few decades, and Libya's urban population is expected to continue expanding, perhaps doubling from present levels by 2020 (figure 9.4). Urban domestic water use is twice as high as rural and so the shift in population, coupled with increasing per capita use in both the urban and rural sectors, could increase domestic water demand over the coming years. However, it must be remembered that depletion rates for domestic water use can be relatively low and so the net effect on total water availability will depend on how domestic waste water is recycled.
- Future estimates of water consumption for all possible purposes indicate total water consumption increasing from 6293.89 million cubic metres in 2006 to 12473.20 million cubic metres in 2020 with an average compound annual growth rate of 5%. In 2020 it is expected that the increase will be 98% of the water consumption in 2006.

- Future water consumption for agricultural purposes is expected to increase. Agriculture is expected to remain the biggest consumer of water with 83% of the estimated water consumption in 2020. Actually, this large increase in water consumption for agricultural use will affect the water reserve. Therefore, the way to guide water consumption in the agricultural sector has to be considered.
- Future water consumption for domestic purposes will increase and the rate of domestic water demand per person will increase from 105.38 cubic metres in 2006 to 150.53 cubic metres in 2020 (table (9.4)). That can be explained by the expected increase of population and their needs for water. It is worth mentioning here that the consumed water quantity in the northern regions will depend, in addition to the groundwater, on waters obtained from desalination plants.
- Estimates of population elasticities show that in the short-run water demand is inelastic. A 10% increase in population will increase water demand for agriculture, domestic and industry uses by around 2.0%, 3.9% and 4.3% respectively. In the long-run water demand for all purposes is highly elastic with respect to population. For example, if the population increases by 10% the water demand for agriculture, domestic and industry uses will increase by around 28%, 17% and 49% respectively (table (8.3) previous chapter).
- Water consumption for industrial uses will increase. The water quantity to be consumed for industrial purposes in 2020 is expected to be about 2% of the total water consumption. Using water for industrial purposes will rely mainly on desalinated water. In spite of the positive relation between

industrial expansion and water demand, and the expected increase of water consumption during the period 2005-2020, the consumed quantity for industrial purposes is considered small, if compared with water quantities consumed for other purposes.

Table (9.4): Forecast of Water Demand for Domestic Use per Person 2006-2020

Years	Population Million	Domestic Water Million Cubic Metre	Domestic Use Per Person (Cubic Metres)
2006	8.5	895.75	105.38
2010	9.6	1147.69	119.55
2015	11.1	1494.92	134.68
2020	12.5	1881.66	150.53

Data source: Table (7.11) previous chapter
General Planning Council, (2006), Report of Libyan Economic and Social Indicators 2006.
http://www.gpc.gov.ly/online/detailsnews.php.

By viewing the data in tables (9.5), (9.6), (9.7) and figure (9.5), the following can be noticed:

- By 2020, as a whole, water demands will almost double in Libya. So, available water in 2020 will be less than half of water demand which means an increase of the shortage over time. This shortage is resulting from the fact that the consumption of water is much greater than the water available.
- By 2020, the population of Libya is projected to become 12.5 million. In 2006, the available renewable fresh water per capita was 459 litres/day (table (9.1) and (9.4)). It is decreased by population growth in 2020 to 332 litres.

- Ground water is considered the main source for irrigation and domestic uses followed by surface water. With the current trend in water use, it is anticipated that within the next decade Libya will have utilised all the potentially available conventional water resources.
- Like water resources, most natural resources on Jifara plain especially soils (over cultivation) and vegetation (overgrazing) will experience pressure resulting from population growth. These activities lead to desegregation and deforestation followed by soil degradation; consequently, soil is a vital, but fragile property. When vegetation is removed and precipitation occurs with high intensity as usual, the runoff water drained from Jebal Naffusah increases across the surface of the plain causing floods and land erosion. As a result of policies as well as the dictates of the inheritance system in Libya, farmlands tend to be fragmented and too small to utilize water efficiently. This problem was especially severe in the long-settled Jifara Plain (Schliephake, 2004: 210).
- Water demand in Libya is growing rapidly and the water deficit will be more than 8 million cubic metre/year in 2020
- The studies about the Great Man-Made River Project showed that 790 million cubic metres of water will be conveyed yearly from the reservoir bed of Morzuk to the level land of Jifara. A further 790 million cubic metres of water will be conveyed yearly from the reservoir bed of Kufra/Sarir to the middle and Green Mountains regions. The water conveyance from south to north will reduce the shortage of water in the northern reservoir beds, but, on the other hand, it will affect the water

reserves of southern basins in the far future (Genera Environmental Authority, 2002).

- If we assume that the life of the Great Man-Made River Project would last about fifty years, then it would be inevitable to rely partially in the northern regions on desalinated waters for domestic and on reused water for agrarian purposes.

Table (9.5): The Expected Future Water Demand in Libya 2006-2020 (Million Cubic Metres/Year)

	2005	2010	2015	2020
Agricultural Use	5060.00	6171.39	7975.77	10311.30
Domestic Use	830.00	1147.69	1494.92	1881.66
Industrial Use	185.00	227.24	259.85	280.24
Total Demand	6075.00	7546.32	9730.54	12473.20

Data source: Table (7. 11) in the previous chapter

Table (9.6): The Expected Future Water Supply in Libya 2006-2020 (Million Cubic Metres/Year)

Year	2005	2010	2015	2020
Underground Water	3430	3430	3430	3430
Surface Water	120	120	120	120
Desalinated Water	135	140	145	150
Treated Water	250	300	400	450
Total Supply	3935	3990	4095	4150

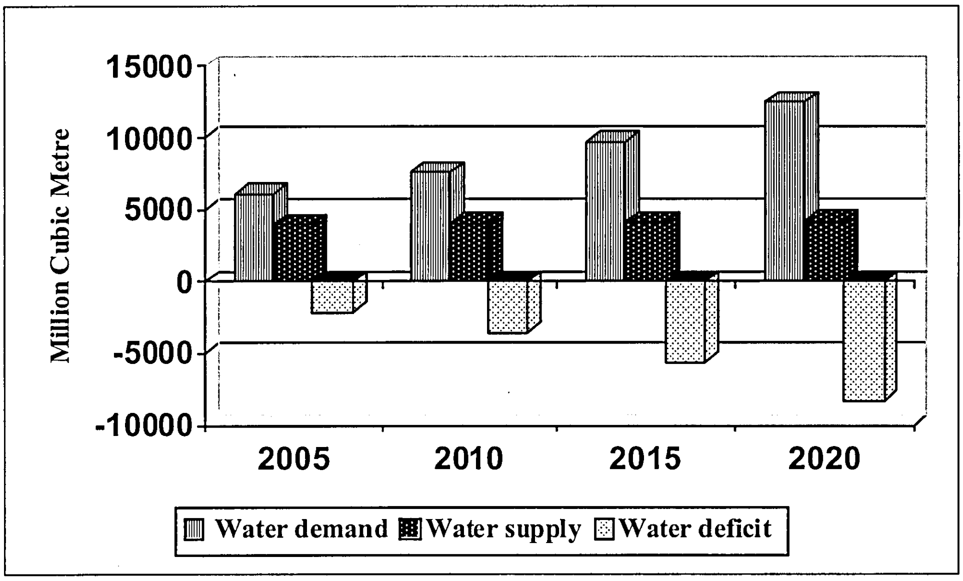
Data source: Al- Ghariani, S.A.1996. Integrated Water Management for Sustainable Development, Conference on Water Resource of the Arab World, Faculty of Agriculture. Al-Fateh University. Tripoli- Libya. (In Arabic).

Table (9.7): Water Deficit in Libya 2005-2020 (Million Cubic Metre)

Year	2005	2010	2015	2020
Total Supply	3935	3990	4095	4150
Total Demand	6075	7546	9730	12473
Water Deficit	-2140	-3556	-5635	-8323

Data source: tables (9.5) and (9.6)

Figure (9.5): Water Deficit in Libya 2005-2020



Data source: table (9.5)

In summary, after comparing our forecasting results for water demand in future with the AlGrianin (1996) forecasts although his forecasting was about the Man-Made River and our forecasts for total water demand in Libya we have found that.

- The future estimates of water consumption for all possible purposes indicate total water consumption is increasing;
- Agriculture is expected to remain the biggest consumer of water;
- Future water consumption for domestic purposes will increase and the rate of water consumption per person will increase as well; and
- Water consumption for industrial uses will increase.

9.4 CONCLUSIONS

The results of the model forecasts based on the three sectors (agriculture, domestic and industry) address several important issues. Income, population and temperature are expected to create a rising demand for water, particularly agriculture and industry products. The industrial, residential, and commercial demand sectors are likely to record the highest growth rates for water. For the most part, this result indicates that short-and long-run water consumption and economic activities are interrelated. The model forecasts show that, for all sectors, water consumption varies directly with population growth.

So, demand for water will continue to rise as a result of population growth and improving standards of living. On the other hand, available water resources are almost constant at around 3.5 billion cubic metres /year including the conveyed water from the south. The deficit is currently covered by over-exploiting the groundwater aquifers, sacrificing water quality for minimal agricultural development.

The future water supply will strongly depend on desalination, treatment, and reuse and to a greater degree on the improvement of irrigation practices.

CHAPTER TEN

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

10.0 INTRODUCTION

Due to increasing global population, urban development and requirements for hydrologic changes due to climate change, nearly 7 billion people in 60 countries could face challenges due to water scarcity (Nature, 2003). Many developing countries confront serious difficulties due to water quality issues.

Like the blood in our veins, water is a necessity to all life forms and pursuits. Consequently, changing global and regional circumstances have increased the need for accurate predictions of both water supply and demand.

This study presents econometric analyses to forecast agricultural, domestic and industrial use of water in Libya and to estimate the determinants of the elasticities of water demand. It examines the effect of price, income, population and temperature on water demand in Libya in the short-run and long-run using annual time series data.

The aim of the material produced in the previous chapters is to investigate the historical relationship between population growth and various uses of water, and to show the future relationship between population growth and water consumption according to the various uses. Within these aims, trends of population growth and their determinants as well as the various water resources in Libya are also dealt with to determine the total water demand in the future.

The main objective of this concluding chapter is to link the research project findings with the literature review. Further objectives of this chapter are to discuss the main limitations of this research project and to provide directions for future research. This chapter is divided into six sections. A summary of major findings is in section 10.1. Contributions to knowledge in Libya will be introduced in section 10.2. Section 10.3 discusses the main limitations of the study. Section 10.4 discusses the achievement of the research aims. The policy recommendations are presented in section 10.5. The last section provides suggestion for future research.

10.1 SUMMARY OF MAJOR FINDINGS

This study focuses on the economic aspects of population growth and water consumption in Libya in the future. Population growth in Libya is very high in the last few years; the rate of Libyan population growth is considered one of the highest rates of population growth in the world. This is explained by the high natality and low mortality and accelerated migration from rural to urban settlement areas as the land cannot support the original inhabitants, which led to a high increase in the population of Libya.

In general, the study concludes that future water consumption for all possible purposes will increase from 6293.89 million cubic metres in 2006 to 12473.20 million cubic metres in 2020, with an average compound annual growth rate of 4.97%. In 2020 it is expected that the increase will be 98% of the water consumption in 2006 (i.e. water demand will almost double in the next fourteen years).

By examining the water use, the results of the study indicate that the agriculture sector will continue to be the major water consumer. It represents about 83% of the estimated water consumption in 2020 and despite the use of pressurized irrigation techniques in practically all farming areas, application rates are still among the highest in the world. Actually, this great increase in water consumption for agricultural use will affect the water reserve. Therefore, the way to guide water consumption in the agriculture sector has to be considered. Agricultural water use will increase from 5204.43 in 2006 to 10311.30 in 2020 as a result of the growing population, and there will be increasing scarcity of water.

The future water consumption for domestic purposes will increase from 895.75 million cubic metres in 2006 to 1881.66 million cubic metres in 2020 with an average compound annual growth rate of 5.4%. This can be explained by the expected increase of population and their needs for water. It is worth mentioning here that the consumed water quantity in the northern regions will depend, in addition to the groundwater, on waters obtained from desalination plants.

For the industrial sector, the water quantity is expected to be about 2% of the total water consumption in 2020. A large number of industries depend on private sources for water supply, including desalination of seawater, as in the case of the chemical, petrochemical, steel, textile and other industries. Today the volume of water used by industries rises, but an increase in demand, with a rate of 2% is forecast, which increases water demand for industry purposes to 280.24 million cubic metres in 2020. Using water for industrial purposes will rely mainly on desalinated water. In spite of the positive relation between industrial expansion and water demand, and the expected increase of water consumption during the period 2006–2020, the consumed quantity for industrial purposes is considered small compared with water quantities consumed for other purposes.

The estimates of population elasticities show that in the short-run water demand is inelastic. A 10% increase in population will increase water demand for agriculture, domestic and industry uses by around 2.0%, 3.9% and 4.3% respectively. While in the long-run water demand for all purposes is highly elastic with respect to population. For example, if the population increases by 10% the water demand for agriculture, domestic and industry uses will increase by around 28%, 17% and 49% respectively.

We find that in the short and long-run price elasticties are negative, suggesting that there is an inverse relationship between water demands and price. Also, these elasticities indicate that water use is generally inelastic with respect to price. These are similar results to those given by Griffin et al., (1990), De Rooy, (1974), Moore et al., (1963) in chapter two. Prices have significant effects for water demand for agriculture, domestic and industry uses. For example, in the long-run, if the price increases by 10% the water demand for agriculture, industry and domestic use will decrease by 2.7%, 1.4% and 4.9% respectively.

The income elasticities are all positive in the short and long-run. This result accords with demand theory, implying that water is a normal good, while a negative value indicates that a commodity is inferior. Income elasticities greater than unity characterise luxury goods where budget shares increase with income, while necessities, having elasticity values between zero and one, experience falls in their budget shares with increases in income. In our case, it is found that the elasticities are between zero and one, implying that a 10% increase in real income would lead to a 1.8% increase in demand for water for agricultural use.

Overall, our results show that the short-run elasticities are less then the long-run elasticities as expected by theory. Also all elasticities in the short-run are less than one. This means that, water demand is inelastic in the short-run.

The estimation results suggest that, in the long-run, water demand for agricultural, domestic and industrial use is highly elastic for population and inelastic for price and income.

10.2 RECONSIDERATION OF THE RESERCH AIMS AND OBJECTIVES

This study has three aims: first, to forecast water consumption according to the various uses; second, to estimate the elasticities of water demand and examine the effect of price, income, population and temperature on water demand in Libya in the short and long-run; third, to estimate the historical relationship between population growth and the various uses of water.

To achieve these aims, an econometric model of Libyan water demand is constructed and estimated for the period 1975-2005, using the Box–Jenkins approach to forecast water demand and the Engle–Granger two-step approach to estimate the short and long-run elasticities of water demand. As a result this study provides considerable information for policy makers concerning current and future Libyan water demand.

The model forecasts and estimates that by 2020, as a whole, water demands will double in Libya. So, available water in 2020 will be less than half of water demand, which means an increase of the shortage in water over time.

The best fitting models are estimated separately for the water demand series from 1975 to 2000 and the tests indicate that the models perform well. The coefficients are all significant, and they satisfy the stationarity and invertibility conditions. Each model has the highest adjusted R^2 and the lowest AIC and SIC values of six candidate models.

From this research, it is learnt how to improve estimates using appropriate diagnostic tests. Most importantly, it is learnt that the source of most statistical problems is omission of relevant variables. Moreover, it is observed that dealing with time series data is complicated. If one is interested in the long-run relationship of variables, at least testing for cointegration is mandatory as most time series economic data are non-stationary.

10.3 CONTRIBUTIONS OF THE STUDY TO KNOWLEDGE

This section summarises the contributions to the body of knowledge that fills the empirical gap in water demand studies in Libya in terms of methodological approach and theoretical underpinnings.

10.3.1 Theoretical Contributions

This study used economic linear regression methodology in order to:

1- Forecast the water demand for agricultural, domestic and industrial use in Libya, using the Box–Jenkins approach.

2- Determine of the elasticities of water demand and examine the effect of price, income, population and temperature on water demand in Libya in the short-run and long-run, using the Engle–Granger two-step approach.

3- Estimate the historical relationship between population growth and the various uses of water.

This methodology combines aspects of water forecasting and elasticity estimation in explaining water demand, an approach necessary for better understanding their decision-making processes.

10.3.2 Practical Contributions

1-This is one of the first academic studies to investigate the following subjects:

- Forecasting and investigating the present relationship between population growth and the various uses of water demand in the current period at the aggregate level: Other studies focus on the disaggregate level. This study is comprehensive in covering the economic aspects of population growth and water consumption. Hence this study could bee seen as a comprehensive source of reference on information about this subject.
- Using the Box-Jenkins approach to estimate and forecast the model of demand of water and the Engle-Granger two step approach to examine the elasticity of income, price, population and temperature in the long and sort-run: This information is expected to add to the current literature on the educational philosophies that researchers, academics and practitioners will find interesting and useful to their work.
- The impact of pricing on water demand in the domestic and industrial water supply sectors is very much a function of price elasticity. Price elasticity is the amount by which demand changes in response to changes in price. It is usually negative for water. Price acts as a strong tool for

reducing demand, but at the same time the total income of suppliers may fall if the volume consumed falls at a greater rate than the price increase. Price rises can result in considerable income increases for the supplier, and contribute to supply maintenance or development, though the role of price as a demand management tool is limited. The finding of this study provide considerable information for policy makers concerning the impact of pricing on water demand for all purposes currently and in the future.

- This research has been written in the English language on the on the subject of population growth and water demand in Libya at the aggregate level. The information, discussions and analysis provided is a contribution to the English literature on the subject.

2-This study contribute to the dialogue among authors, providing knowledge about the causes around economic resources and other issues such as population and water.

10.4 POLICY RECOMMENDATIONS

As the Libyan population grows, more water will be required to satisfy its needs. The present limited water resources will become even more limited. This very much-needed water in the future might come at a high financial and ecological price. Currently, water demand exceeds the conventional water resource capacities, creating an urgent need for integrated water resource management with special focus on non-conventional water resources namely, sea water desalination and wastewater reuse. The following recommendations are made in relation to the future of water demand in Libya:

1. The agricultural sector has the highest consumption of water and a very low share in the country's economic sustainability. It is regarded as the main cause of the shortage problem. Therefore it is recommended that no expansion should be allowed in reclaiming agricultural land. It is obvious that a self-sufficiency policy for food is beyond reach in Libya. Therefore it is strongly recommended that more reliance on the world food market must be permitted since the country has the means to do so.
2. Institutional reforms should be considered, such as the creation of a Water Resources National Council with power to set an overall policy and to avoid any administrative conflicts between end water users. For example, Water allocation management of the transported groundwater from the south to the coastal regions in the north that have water deficit as in the Gefarah plain and the Nafusah/al- Hamada areas is necessary.
3. Water allocation should be based entirely on social and economic importance. Therefore it should be sufficiently allocated to the domestic sector as a first priority because of life necessity, followed by satisfying the industrial activities requirements, and finally to the agricultural sector. In this respect an efficient and suitable irrigation system should be adapted to minimise the overuse of water. Indeed the domestic and industrial water demand is comparably small and the consumption could be reclaimed and reused for agricultural purposes.
4. The installation of suitable capacities of desalination plants in the urban areas to meet the domestic water demands will certainly play an

important role in sustaining the economic development of the country. Also, agricultural area locations that make use of the conveyance of treated wastewater are an economical source of water supply that surrounds most of the urban areas in the northern regions. Therefore it is strongly recommended that the installation of more wastewater treatment plants is realised since the sewage has to be treated anyhow for environmental protection reasons.

5. It is essential to introduce a suitable water-pricing system for all the users in all sectors as a conservation measure for water resources. In this framework the following measure could be adapted as tool to discourage inefficient water use: All water users, whether in agriculture, industry, or domestic sector, ought to be metered. The water authority must license all water resources users and permissions have to be renewed annually. Each license should prescribe the quantity of water that can be withdrawn from any source for any purpose. The authorities must also be given the right of unlimited access to water meters for regular inspections.

10.5 LIMITATIONS OF THE STUDY

This study has investigated water demand in future, elasticities and the relationship between population growth and water consumption in Libya. However, there are, as in any type of research, some limitations that the researcher encountered in the process as explained below:

- Reliability of data is crucial for any empirical analysis. The unavailability of observed data on quantities of water consumed for various purposes.

This may not necessarily correspond to actual quantities used and hence constitutes a major limitation to this study.

- In Libya, as a developing country, data and information needed for research are limited and sometimes unavailable. The problems in these countries include short time series of data, lack of monthly and quarterly data, missing observations and variables and the imposition of secrecy on some data and information. This is due to technical inexperience. In addition to the above problems, some unpublished data can usually only be obtained through a personal contact. For these reasons this study used data for the period 1975-2005. Annual data are the only data available in Libya. The process of compiling national accounts takes some time and final estimators are not usually ready for publication until about two or three years after the end of the year under consideration. This is due to the non-availability of quarterly statistical data.
- Approximately seven weeks were spent at the first stage of collecting data from the Ministry of General Planning, General Water Authority and the General Investment of the Great Man-Made River. However, historical population data was taken from Great Socialist People's Libyan Arab Jamahiriya and Jamahiriya Statistical Year- book for the years from 1975 to 2005. Historical data and projections for income were obtained from the Central Bank of Libya and total population is used as the determinant of domestic, industrial and as agricultural use of water.

For the above reasons, this study forecasts water demand at the aggregate level, because the data are limited and not available to the extent needed for disaggregate purposes.

10.6 SUGGESTIONS FOR FUTURE RESEARCH

This thesis has possibly not answered all the relevant questions and has been unable to overcome some of the methodological limitations encountered during the study. The following are suggestions to enrich the results for future research in water demand studies, not only in Libya but also in other developing countries.

- To effectively come up with more reliable estimates of water demand and time allocated to access water from importance sources, it is recommended that future studies employ actual (observed) quantities of water consumed on domestic water activities per source and time devoted to water collection.
- Research is needed to establish the basic monthly water requirement for water demand activities in agricultural, domestic and industrial use. This would be helpful in water pricing where a certain basic minimum is considered essential and could be supplied freely, after which consumption beyond this basic minimum would be charged.
- Further investigations are needed to establish whether interventions in improved water supply in known communities have improved. This is needed to give policy-makers the required feedback to improve on policy formulation and implementation strategies where necessary.

- It would be interesting to apply this model after the estimation period of this study when the data becomes available, and compare the results with those obtained in the present study.

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APPENDICES

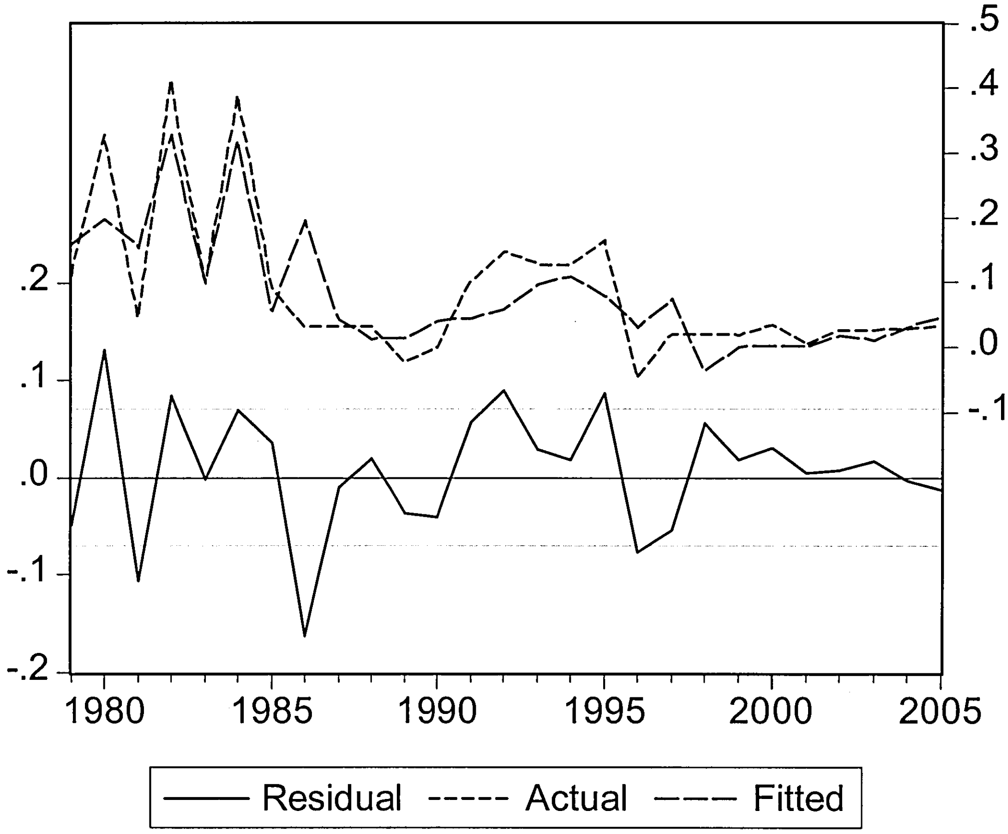
Appendix A

THE BEST MODELS FOR TOTAL WATER DEMAND FOR AGRICULTURAL, DOMESTIC AND INDUSTRIAL USE.

Residual Tests

Figure (A7.1)

First Difference for Natural Logarithm of Total Water Demand ($d\ln W$)



The residuals do not seem to have a trend, they appear to have a mean value close to zero, and the variance of the series does not appear to change too much over time. There is no obvious trend in the residual series in the figure (A7.1) and it appears stationary.

Table (A7.1)

Check the Size of the Differences between the Fitted and Actual Values

<table>
<tr><th>Obs</th><th>Actual</th><th>Fitted</th><th>Residual</th><th>Residual Plot</th></tr>
<tr><td>1979</td><td>0.11030</td><td>0.15924</td><td>-0.04894</td><td>| .* | . |</td></tr>
<tr><td>1980</td><td>0.32744</td><td>0.19682</td><td>0.13063</td><td>| . | . * |</td></tr>
<tr><td>1981</td><td>0.04600</td><td>0.15243</td><td>-0.10643</td><td>| * . | . |</td></tr>
<tr><td>1982</td><td>0.41145</td><td>0.32715</td><td>0.08430</td><td>| . | .* |</td></tr>
<tr><td>1983</td><td>0.09774</td><td>0.09976</td><td>-0.00202</td><td>| . * . |</td></tr>
<tr><td>1984</td><td>0.38736</td><td>0.31803</td><td>0.06933</td><td>| . | * |</td></tr>
<tr><td>1985</td><td>0.09093</td><td>0.05555</td><td>0.03538</td><td>| . | *. |</td></tr>
<tr><td>1986</td><td>0.03186</td><td>0.19481</td><td>-0.16295</td><td>|* . | . |</td></tr>
<tr><td>1987</td><td>0.03232</td><td>0.04272</td><td>-0.01040</td><td>| . *| . |</td></tr>
<tr><td>1988</td><td>0.03208</td><td>0.01259</td><td>0.01950</td><td>| . |* . |</td></tr>
<tr><td>1989</td><td>-0.02290</td><td>0.01373</td><td>-0.03664</td><td>| . * | . |</td></tr>
<tr><td>1990</td><td>-0.00066</td><td>0.04093</td><td>-0.04160</td><td>| . * | . |</td></tr>
<tr><td>1991</td><td>0.10131</td><td>0.04386</td><td>0.05745</td><td>| . | *. |</td></tr>
<tr><td>1992</td><td>0.14758</td><td>0.05812</td><td>0.08945</td><td>| . | . * |</td></tr>
<tr><td>1993</td><td>0.12608</td><td>0.09663</td><td>0.02945</td><td>| . | * . |</td></tr>
<tr><td>1994</td><td>0.12727</td><td>0.10926</td><td>0.01801</td><td>| . |* . |</td></tr>
<tr><td>1995</td><td>0.16515</td><td>0.07882</td><td>0.08633</td><td>| . | .* |</td></tr>
<tr><td>1996</td><td>-0.04588</td><td>0.03086</td><td>-0.07675</td><td>| *. | . |</td></tr>
<tr><td>1997</td><td>0.01918</td><td>0.07361</td><td>-0.05443</td><td>| .* | . |</td></tr>
<tr><td>1998</td><td>0.01932</td><td>-0.03595</td><td>0.05527</td><td>| . | *. |</td></tr>
<tr><td>1999</td><td>0.01810</td><td>-0.00061</td><td>0.01871</td><td>| . |* . |</td></tr>
<tr><td>2000</td><td>0.03339</td><td>0.00262</td><td>0.03078</td><td>| . | * . |</td></tr>
<tr><td>2001</td><td>0.00431</td><td>-0.00023</td><td>0.00453</td><td>| . * . |</td></tr>
<tr><td>2002</td><td>0.02622</td><td>0.01834</td><td>0.00788</td><td>| . |* . |</td></tr>
<tr><td>2003</td><td>0.02646</td><td>0.00903</td><td>0.01743</td><td>| . |* . |</td></tr>
<tr><td>2004</td><td>0.02706</td><td>0.03012</td><td>-0.00306</td><td>| . * . |</td></tr>
<tr><td>2005</td><td>0.03258</td><td>0.04548</td><td>-0.01290</td><td>| . *| . |</td></tr>
</table>

Table (A7.2)

Check the Residual Correlogram for ARMA (3,1) if White Noise

With Zero Lag

Date: 05/08/07 Time: 11:06						
Sample: 1979 2005						
Included observations: 27						
Q-statistic probabilities adjusted for 4 ARMA term(s)						
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
.**| . |	.**| . |	1	-0.269	-0.269	2.1839	
. | . |	. *| . |	2	-0.034	-0.115	2.2200	
. | . |	. | . |	3	0.007	-0.037	2.2216	
. *| . |	. *| . |	4	-0.059	-0.078	2.3388	
. *| . |	. *| . |	5	-0.061	-0.111	2.4698	0.116
***| . |	***| . |	6	-0.327	-0.431	6.4447	0.040
. |* . |	. *| . |	7	0.140	-0.164	7.2148	0.065
. |* . |	. | . |	8	0.098	0.008	7.6140	0.107
. *| . |	. *| . |	9	-0.087	-0.118	7.9405	0.160
. |* . |	. | . |	10	0.118	-0.030	8.5766	0.199
. |* . |	. |* . |	11	0.123	0.071	9.3142	0.231
. *| . |	. *| . |	12	-0.102	-0.187	9.8581	0.275

Table (A7. 3)

Check the Residual Correlogram for ARMA (3,1) if White Noise

With sixteen Lags

Date: 05/08/07 Time: 11:10						
Sample: 1979 2005						
Included observations: 27						
Q-statistic probabilities adjusted for 4 ARMA term(s)						
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
.**| . |	.**| . |	1	-0.369	-0.269	1.1839	
. | . |	. *| . |	2	-0.134	-0.115	3.2200	
. | . |	. | . |	3	0.107	-0.137	2.2216	
. *| . |	. *| . |	4	-0.159	-0.078	3.3388	
. *| . |	. *| . |	5	-0.161	-0.211	2.4698	0.126
***| . |	***| . |	6	-0.427	-0.431	5.4447	0.030
. |* . |	. *| . |	7	0.140	-0.164	7.2148	0.075
. |* . |	. | . |	8	0.098	0.108	8.6140	0.107
. *| . |	. *| . |	9	-0.387	-0.118	7.9405	0.150
. |* . |	. | . |	10	0.128	-0.030	8.5766	0.189
. |* . |	. |* . |	11	0.113	0.061	8.3142	0.221
. *| . |	. *| . |	12	-0.102	-0.177	9.8581	0.575

From tables (A7.2) and (A7.3) we can seen that the Q-statistics are significantly different from zero. For the model ARMA (3,1) all the residual correlations are within the bands and all of the Q-statistics have a p-value grater than 0.05. This means that at the 5% significance level we accept the null hypothesis that all the autocorrelation coefficients are jointly equal to zero. This result indicates that there is no autocorrelation in the residuals, so that they are likely to be white noise.

Table (A7.4)

Test for Autocorrelation in the Residuals: the Serial Correlation Lagrange Multiplier test (LM) with Two Lags

Breusch-Godfrey Serial Correlation LM Test:				
F-statistic	25.12632	Probability		0.000003
Obs*R-squared	19.20813	Probability		0.000067
Test Equation:				
Dependent Variable: RESID				
Method: Least Squares				
Date: 05/08/07 Time: 11:11				
Presample missing value lagged residuals set to zero.				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.009803	0.025310	0.387329	0.7026
AR(1)	0.194589	0.135310	1.438102	0.1659
AR(2)	-0.273735	0.202835	-1.349542	0.1922
AR(3)	-0.028890	0.128882	-0.224160	0.8249
MA(1)	-1.414053	0.213654	-6.618437	0.0000
RESID(-1)	-0.170672	0.166569	-1.024630	0.3178
RESID(-2)	0.056213	0.166374	0.337871	0.7390
R-squared	0.711412	Mean dependent var		0.007346
Adjusted R-squared	0.624836	S.D. dependent var		0.063949
S.E. of regression	0.039169	Akaike info criterion		-3.423455
Sum squared resid	0.030684	Schwarz criterion		-3.087497
Log likelihood	53.21664	F-statistic		8.217168
Durbin-Watson stat	2.015187	Prob(F-statistic)		0.000144

Table (A7. 5)

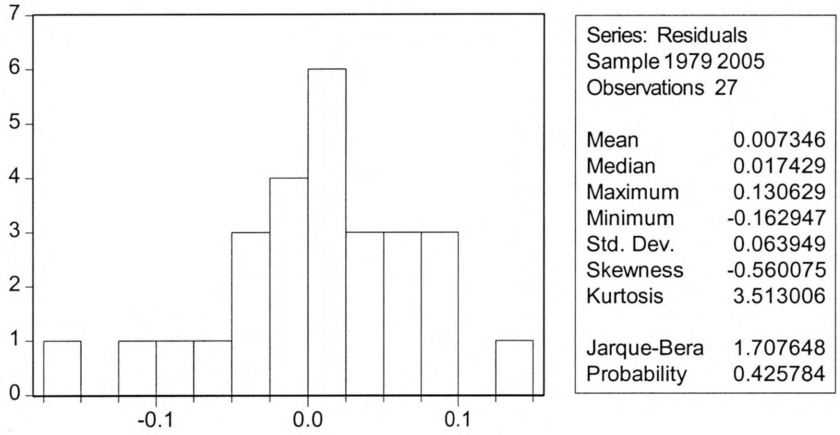
Test for Autocorrelation in the Residuals: the Serial Correlation Lagrange Multiplier test (LM) with Two Lags

Breusch-Godfrey Serial Correlation LM Test:				
F-statistic	52.34662	Probability		0.000000
Obs*R-squared	19.16366	Probability		0.000012
Test Equation:				
Dependent Variable: RESID				
Method: Least Squares				
Date: 05/08/07 Time: 11:14				
Presample missing value lagged residuals set to zero.				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.006035	0.022236	0.271407	0.7887
AR(1)	0.179910	0.125413	1.434539	0.1661
AR(2)	-0.239630	0.172184	-1.391708	0.1786
AR(3)	-0.057003	0.096326	-0.591777	0.5603
MA(1)	-1.407307	0.208184	-6.759930	0.0000
RESID(-1)	-0.172632	0.162919	-1.059616	0.3014
R-squared	0.709765	Mean dependent var		0.007346
Adjusted R-squared	0.640661	S.D. dependent var		0.063949
S.E. of regression	0.038334	Akaike info criterion		-3.491837
Sum squared resid	0.030859	Schwarz criterion		-3.203874
Log likelihood	53.13980	F-statistic		10.27103
Durbin-Watson stat	1.979665	Prob(F-statistic)		0.000044

From tables (A7.4) and (A7.5) we can notice that the p-value is greater than 0.05, so that we accept the null hypothesis of zero autocorrelation in the residuals, this is further evidence that the residuals are white noise.

Figure (A7.2)

Normality of the Residuals



In figure (7.3) the p-value (=0.43) is higher than 0.05, so that we accept the null hypothesis of normality at the 5% significance level.

Table (A7. 6)

Test if the Series is Stationary by Using Unit Root test with Zero Lag

ADF Test Statistic	-6.512122	1% Critical Value*		-2.6560
		5% Critical Value		-1.9546
		10% Critical Value		-1.6226
*MacKinnon critical values for rejection of hypothesis of a unit root.				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(RESID01)				
Method: Least Squares				
Date: 05/08/07 Time: 11:36				
Sample(adjusted): 1980 2005				
Included observations: 26 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID01(-1)	-1.247804	0.191612	-6.512122	0.0000
R-squared	0.629053	Mean dependent var		0.001386
Adjusted R-squared	0.629053	S.D. dependent var		0.103206
S.E. of regression	0.062858	Akaike info criterion		-2.658176
Sum squared resid	0.098778	Schwarz criterion		-2.609787
Log likelihood	35.55628	Durbin-Watson stat		1.784396

Table (A7.7)

Test if the Series is Stationary by Using Unit Root Test with One Lag

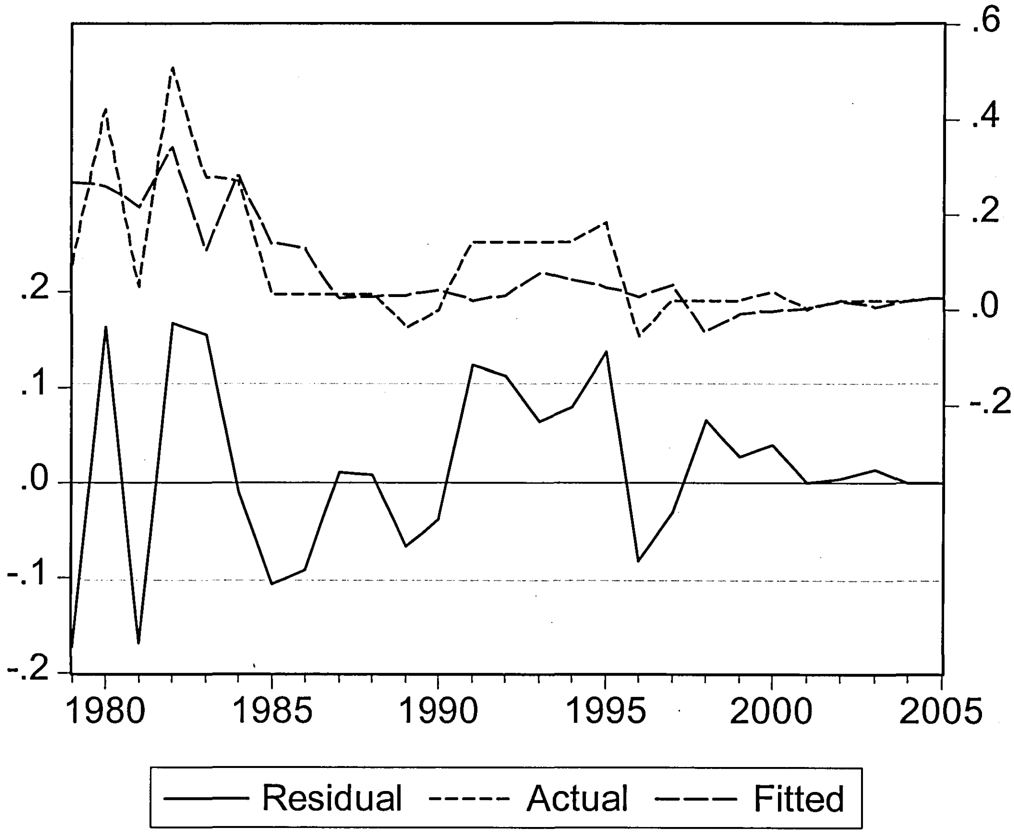
ADF Test Statistic	-4.258952	1% Critical Value*		-2.6603
		5% Critical Value		-1.9552
		10% Critical Value		-1.6228
*MacKinnon critical values for rejection of hypothesis of a unit root.				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(RESID01)				
Method: Least Squares				
Date: 05/08/07 Time: 11:38				
Sample(adjusted): 1981 2005				
Included observations: 25 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID01(-1)	-1.288081	0.302441	-4.258952	0.0003
D(RESID01(-1))	0.076084	0.190131	0.400167	0.6927
R-squared	0.640617	Mean dependent var		-0.005741
Adjusted R-squared	0.624991	S.D. dependent var		0.098587
S.E. of regression	0.060373	Akaike info criterion		-2.699937
Sum squared resid	0.083832	Schwarz criterion		-2.602427
Log likelihood	35.74921	Durbin-Watson stat		1.680522

As can be seen from tables (A7.6) and (A7.7), the ADF test statistic is -4.26 and -6.51 with a lag length of one and not included any lag respectively, which are much larger and more negative than any of the critical values. This is an indication that we can reject the null hypothesis of a unit root in the residual series. In other words, the residuals appear to be a stationary series. This is further evidence that the residuals are white noise

Residual Tests

Figure (A7.3)

First Difference for Natural Logarithm for Water Demand for Agriculture ($\mathrm{d}\ln W_A$)



The residuals do not seem to have a trend, they appear to have a mean value close to zero, and the variance of the series does not appear to change too much over time. There is no obvious trend in the series in the figure (A7.3) and it appears stationary.

Table (A7.8)

Check the Size of the Differences between the Fitted and Actual Values

obs	Actual	Fitted	Residual	Residual Plot
1979	0.09347	0.26629	-0.17282	|* . | . |
1980	0.42158	0.25934	0.16223	| . | . * |
1981	0.04674	0.21566	-0.16891	|* . | . |
1982	0.50851	0.34193	0.16659	| . | . *|
1983	0.27763	0.12357	0.15407	| . | . * |
1984	0.26912	0.27976	-0.01065	| . *| . |
1985	0.03244	0.13958	-0.10715	| * | . |
1986	0.03250	0.12552	-0.09302	| .* | . |
1987	0.03247	0.02241	0.01006	| . |* . |
1988	0.03247	0.02533	0.00714	| . |* . |
1989	-0.03984	0.02820	-0.06804	| . * | . |
1990	0.00000	0.03901	-0.03901	| . * | . |
1991	0.13976	0.01704	0.12272	| . | . * |
1992	0.13976	0.02775	0.11202	| . | .* |
1993	0.13976	0.07548	0.06428	| . | * . |
1994	0.13976	0.06065	0.07912	| . | *. |
1995	0.18192	0.04585	0.13607	| . | . * |
1996	-0.05649	0.02648	-0.08297	| .* | . |
1997	0.01784	0.04983	-0.03199	| . * | . |
1998	0.01784	-0.04742	0.06526	| . | *. |
1999	0.01784	-0.00874	0.02658	| . | * . |
2000	0.03548	-0.00336	0.03884	| . | * . |
2001	0.00000	6.3E-05	-6.3E-05	| . * . |
2002	0.01804	0.01429	0.00375	| . * . |
2003	0.01777	0.00470	0.01307	| . |* . |
2004	0.01791	0.01810	-0.00019	| . * . |
2005	0.02221	0.02327	-0.00106	| . * . |

Table (A7.9)

Check the Residual Correlogram for ARMA (3,1) if White Noise with Zero Lag

Date: 05/08/07 Time: 11:52						
Sample: 1979 2005						
Included observations: 27						
Q-statistic probabilities adjusted for 4 ARMA term(s)						
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. *| . |	. *| . |	1	-0.137	-0.137	0.5640	
. | . |	. | . |	2	0.010	-0.009	0.5674	
. *| . |	. *| . |	3	-0.104	-0.106	0.9210	
. *| . |	. *| . |	4	-0.060	-0.091	1.0416	
. *| . |	. *| . |	5	-0.081	-0.108	1.2743	0.259
. *| . |	.**| . |	6	-0.141	-0.192	2.0179	0.365
. | . |	. *| . |	7	-0.018	-0.102	2.0305	0.566
. | . |	. | . |	8	0.052	-0.009	2.1437	0.709
. | . |	. | . |	9	0.014	-0.045	2.1521	0.828
. | . |	. *| . |	10	-0.019	-0.085	2.1691	0.904
. |* . |	. |* . |	11	0.149	0.100	3.2533	0.861
. | . |	. |* . |	12	0.060	0.073	3.4408	0.904

Table (A7.10)

Check the Residual Correlogram for ARMA (3,1) if White Noise with Sixteen Lags

Date: 05/08/07 Time: 11:54						
Sample: 1979 2005						
Included observations: 27						
Q-statistic probabilities adjusted for 4 ARMA term(s)						
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. *| . |	. *| . |	1	-0.137	-0.137	0.5640	
. | . |	. | . |	2	0.010	-0.009	0.5674	
. *| . |	. *| . |	3	-0.104	-0.106	0.9210	
. *| . |	. *| . |	4	-0.060	-0.091	1.0416	
. *| . |	. *| . |	5	-0.081	-0.108	1.2743	0.259
. *| . |	.**| . |	6	-0.141	-0.192	2.0179	0.365
. | . |	. *| . |	7	-0.018	-0.102	2.0305	0.566
. | . |	. | . |	8	0.052	-0.009	2.1437	0.709
. | . |	. | . |	9	0.014	-0.045	2.1521	0.828
. | . |	. *| . |	10	-0.019	-0.085	2.1691	0.904
. |*. |	. |*. |	11	0.149	0.100	3.2533	0.861
. | . |	. |*. |	12	0.060	0.073	3.4408	0.904

From tables (A7.9) and (A7.10) we can seen that the Q-statistics are significantly different from zero. For the model ARMA (3,1) all the residual correlations are within the bands and all of the Q-statistics have a p-value grater than 0.05. This means that at the 5% significance level we accept the null hypothesis that all the autocorrelation coefficients are jointly equal to zero. This result indicates that there is no autocorrelation in the residuals, so that they are likely to be white noise.

Table (A7.11)

Test for Autocorrelation in the Residuals: the Serial Correlation Lagrange Multiplier (LM) Test with Two Lags

Breusch-Godfrey Serial Correlation LM Test:				
F-statistic	1.152379	Probability		0.335989
Obs*R-squared	2.205047	Probability		0.332032
Test Equation:				
Dependent Variable: RESID				
Method: Least Squares				
Date: 05/08/07 Time: 11:56				
Presample missing value lagged residuals set to zero.				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.018776	0.031217	0.601479	0.5543
AR(1)	0.336567	0.343598	0.979537	0.3390
AR(2)	-0.503567	0.526899	-0.955718	0.3506
AR(3)	0.165336	0.318910	0.518443	0.6098
MA(1)	0.000206	0.000234	0.879381	0.3896
RESID(-1)	-0.459133	0.395634	-1.160502	0.2595
RESID(-2)	0.171481	0.401162	0.427462	0.6736
R-squared	0.081668	Mean dependent var		0.014293
Adjusted R-squared	-0.193831	S.D. dependent var		0.093710
S.E. of regression	0.102390	Akaike info criterion		-1.501635
Sum squared resid	0.209676	Schwarz criterion		-1.165677
Log likelihood	27.27207	F-statistic		0.296438

Table (A7.12)

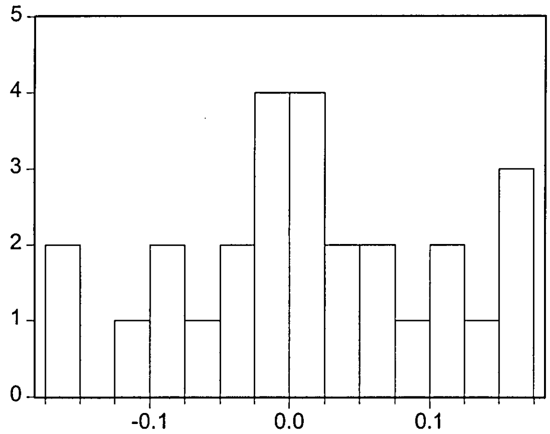
Test for Autocorrelation in the Residuals: the Serial Correlation Lagrange Multiplier (LM) Test with Zero Lags

Breusch-Godfrey Serial Correlation LM Test:				
F-statistic	2.207964	Probability		0.152159
Obs*R-squared	1.978516	Probability		0.159547
Test Equation:				
Dependent Variable: RESID				
Method: Least Squares				
Date: 05/08/07 Time: 11:57				
Presample missing value lagged residuals set to zero.				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.024074	0.028089	0.857058	0.4011
AR(1)	0.290691	0.319993	0.908431	0.3740
AR(2)	-0.347151	0.371662	-0.934050	0.3609
AR(3)	0.051759	0.172902	0.299354	0.7676
MA(1)	0.000239	0.000217	1.100858	0.2834
RESID(-1)	-0.438158	0.384864	-1.138475	0.2677
R-squared	0.073278	Mean dependent var		0.014293
Adjusted R-squared	-0.147370	S.D. dependent var		0.093710
S.E. of regression	0.100378	Akaike info criterion		-1.566614
Sum squared resid	0.211591	Schwarz criterion		-1.278651
Log likelihood	27.14929	F-statistic		0.332105
Durbin-Watson stat	1.825120	Prob(F-statistic)		0.887813

From tables (A7.11), (A7.12) we can notice that the p-value is greater than 0.05, so that we accept the null hypothesis of zero autocorrelation in the residuals, this is further evidence that the residuals are white noise.

Figure (A7.4)

Normality of the Residuals



Series: Residuals	
Sample 1979 2005	
Observations 27	
Mean	0.014293
Median	0.007138
Maximum	0.166586
Minimum	-0.172819
Std. Dev.	0.093710
Skewness	-0.162963
Kurtosis	2.449830
Jarque-Bera	0.460029
Probability	0.794522

In figure (7.4) the p-value (=0.79) is higher than 0.05, so that we accept the null hypothesis of normality at the 5% significance level.

Table (A7.13)

Test if the Series is Stationary by using Unit Root Test with Zero Lag

ADF Test Statistic	-5.914053	1% Critical Value*		-2.6560
		5% Critical Value		-1.9546
		10% Critical Value		-1.6226
*MacKinnon critical values for rejection of hypothesis of a unit root.				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(RESID02)				
Method: Least Squares				
Date: 05/08/07 Time: 12:03				
Sample(adjusted): 1980 2005				
Included observations: 26 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID02(-1)	-1.098533	0.185750	-5.914053	0.0000
R-squared	0.582187	Mean dependent var		0.006606
Adjusted R-squared	0.582187	S.D. dependent var		0.138961
S.E. of regression	0.089822	Akaike info criterion		-1.944263
Sum squared resid	0.201701	Schwarz criterion		-1.895875
Log likelihood	26.27542	Durbin-Watson stat		1.640593

Table (A7.14)

Test if the Series is Stationary by using Unit Root Test with Zero Lag

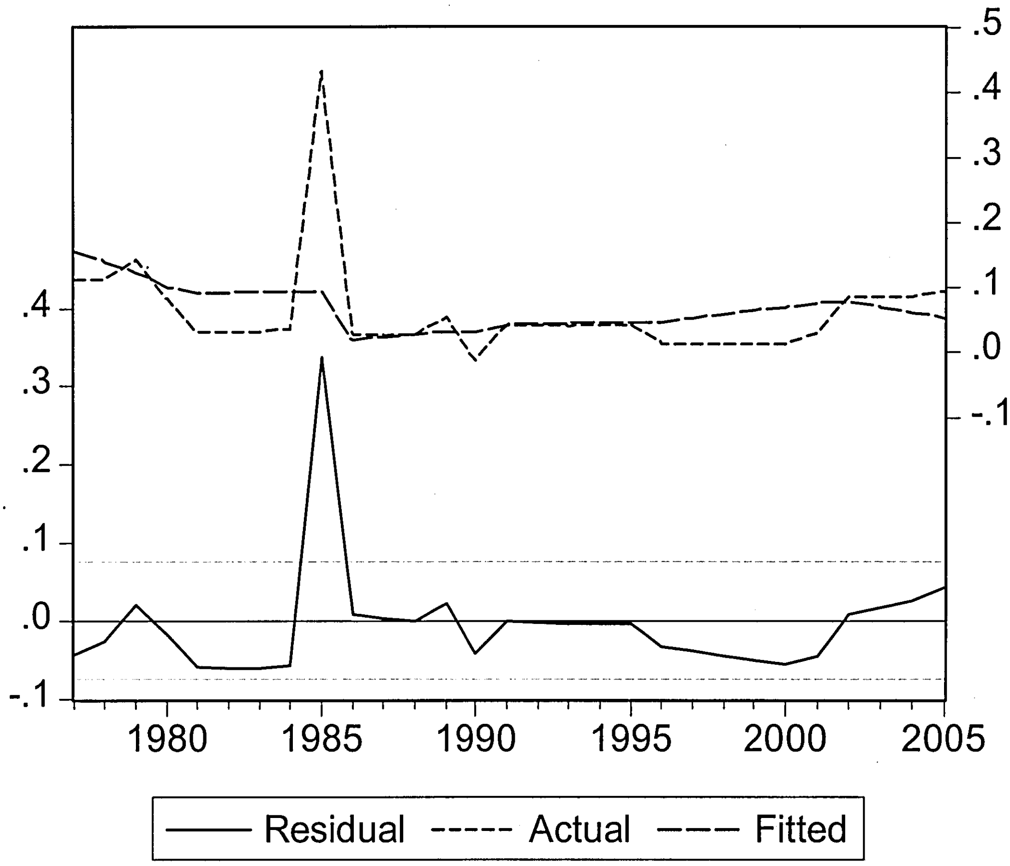
ADF Test Statistic	-3.315509	1% Critical Value*		-2.6603
		5% Critical Value		-1.9552
		10% Critical Value		-1.6228
*MacKinnon critical values for rejection of hypothesis of a unit root.				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(RESID02)				
Method: Least Squares				
Date: 05/08/07 Time: 12:03				
Sample(adjusted): 1981 2005				
Included observations: 25 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID02(-1)	-0.932082	0.281128	-3.315509	0.0030
D(RESID02(-1))	-0.039015	0.182522	-0.213757	0.8326
R-squared	0.521869	Mean dependent var		-0.006532
Adjusted R-squared	0.501081	S.D. dependent var		0.124258
S.E. of regression	0.087769	Akaike info criterion		-1.951600
Sum squared resid	0.177178	Schwarz criterion		-1.854090
Log likelihood	26.39500	Durbin-Watson stat		1.521448

As can be seen from tables (A7.13) and (A7.14), the ADF test statistic is -5.91 and -3.32 with a lag length of one and not included any lag respectively, which are much larger and more negative than any of the critical values. This is an indication that we can reject the null hypothesis of a unit root in the residual series. In other words, the residuals appear to be a stationary series. This is further evidence that the residuals are white noise

Residual Tests

Figure (A7.5)

First difference for Natural Logarithm for Water Demand for Domestic ($d \ln W_D$)



The residuals do not seem to have a trend, they appear to have a mean value close to zero, and the variance of the series does not appear to change too much over time. There is no obvious trend in the series in figure (A7.5) and it appears stationary.

Table (A7.15)

Check the Size of the Differences between the Fitted and Actual Values

obs	Actual	Fitted	Residual	Residual Plot
1977	0.11243	0.15623	-0.04380	| .* | . |
1978	0.11245	0.13922	-0.02677	| . *| . |
1979	0.14313	0.12286	0.02027	| . |* . |
1980	0.08378	0.10124	-0.01745	| . *| . |
1981	0.03248	0.09185	-0.05937	| .* | . |
1982	0.03245	0.09268	-0.06022	| .* | . |
1983	0.03244	0.09348	-0.06104	| .* | . |
1984	0.03593	0.09425	-0.05832	| .* | . |
1985	0.43159	0.09432	0.33727	| . | . *|
1986	0.02703	0.01839	0.00863	| . * . |
1987	0.02664	0.02310	0.00354	| . * . |
1988	0.02665	0.02771	-0.00105	| . * . |
1989	0.05486	0.03213	0.02273	| . |* . |
1990	-0.01156	0.03096	-0.04252	| .* | . |
1991	0.04181	0.04260	-0.00079	| . * . |
1992	0.04210	0.04353	-0.00143	| . * . |
1993	0.04114	0.04438	-0.00324	| . * . |
1994	0.04211	0.04537	-0.00326	| . * . |
1995	0.04192	0.04614	-0.00422	| . * . |
1996	0.01390	0.04692	-0.03302	| . *| . |
1997	0.01390	0.05305	-0.03916	| . *| . |
1998	0.01390	0.05895	-0.04504	| .* | . |
1999	0.01391	0.06461	-0.05070	| .* | . |
2000	0.01390	0.07006	-0.05616	| .* | . |
2001	0.02918	0.07530	-0.04612	| .* | . |
2002	0.08526	0.07740	0.00786	| . * . |
2003	0.08527	0.06865	0.01662	| . |* . |
2004	0.08526	0.06023	0.02503	| . |* . |
2005	0.09409	0.05214	0.04195	| . |* . |

Table (A7.16)

Check the Residual Correlogram for ARMA (3,1) if White Noise with Sixteen Lags

Date: 05/08/07 Time: 12:27						
Sample: 1977 2005						
Included observations: 29						
Q-statistic probabilities adjusted for 2 ARMA term(s)						
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. | . |	. | . |	1	0.038	0.038	0.0459	
. | . |	. | . |	2	-0.040	-0.041	0.0987	
.*| . |	.*| . |	3	-0.085	-0.083	0.3512	0.553
.*| . |	.*| . |	4	-0.074	-0.070	0.5479	0.760
.*| . |	.*| . |	5	-0.150	-0.154	1.3932	0.707
. | . |	. | . |	6	0.063	0.060	1.5481	0.818
. | . |	.*| . |	7	-0.048	-0.080	1.6410	0.896
.*| . |	.*| . |	8	-0.100	-0.127	2.0680	0.913
. | . |	. | . |	9	-0.001	-0.014	2.0681	0.956
. | . |	. | . |	10	0.002	-0.039	2.0682	0.979
.*| . |	.*| . |	11	-0.084	-0.102	2.4173	0.983
.*| . |	.*| . |	12	-0.089	-0.139	2.8323	0.985

Table (A7.17)

Check the Residual Correlogram for ARMA (3,1) if White Noise with Zero lag

Date: 05/08/07 Time: 12:28						
Sample: 1977 2005						
Included observations: 29						
Q-statistic probabilities adjusted for 2 ARMA term(s)						
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. | . |	. | . |	1	0.038	0.038	0.0459	
. | . |	. | . |	2	-0.040	-0.041	0.0987	
.*| . |	.*| . |	3	-0.085	-0.083	0.3512	0.553
.*| . |	.*| . |	4	-0.074	-0.070	0.5479	0.760
.*| . |	.*| . |	5	-0.150	-0.154	1.3932	0.707
. | . |	. | . |	6	0.063	0.060	1.5481	0.818
. | . |	.*| . |	7	-0.048	-0.080	1.6410	0.896
.*| . |	.*| . |	8	-0.100	-0.127	2.0680	0.913
. | . |	. | . |	9	-0.001	-0.014	2.0681	0.956
. | . |	. | . |	10	0.002	-0.039	2.0682	0.979
.*| . |	.*| . |	11	-0.084	-0.102	2.4173	0.983
.*| . |	.*| . |	12	-0.089	-0.139	2.8323	0.985

From tables (A8.16) and (A8.17) we can seen that the Q-statistic are significantly different from zero. For the model ARMA (1,1) all the residual correlations are within the bands and all of the Q-statistics have a p-value grater than 0.05. This means that at the 5% significance level we accept the null hypothesis that all the autocorrelation coefficients are jointly equal to zero. This result indicates that there is no autocorrelation in the residuals, so that they are likely to be white noise.

Table (A7.18)

Test for Autocorrelation in the Residuals: the Serial Correlation Lagrange Multiplier (LM) Test with Two lags

Breusch-Godfrey Serial Correlation LM Test:				
F-statistic	0.040262	Probability		0.960603
Obs*R-squared	0.000000	Probability		1.000000
Test Equation:				
Dependent Variable: RESID				
Method: Least Squares				
Date: 05/08/07 Time: 12:29				
Presample missing value lagged residuals set to zero.				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000301	0.009372	0.032126	0.9746
AR(1)	-0.008193	0.135252	-0.060577	0.9522
MA(1)	-0.000926	0.040379	-0.022942	0.9819
RESID(-1)	0.055094	0.251850	0.218756	0.8287
RESID(-2)	-0.027596	0.239320	-0.115308	0.9092
R-squared	-0.003349	Mean dependent var		-0.005855
Adjusted R-squared	-0.170573	S.D. dependent var		0.072719
S.E. of regression	0.078677	Akaike info criterion		-2.091336
Sum squared resid	0.148563	Schwarz criterion		-1.855596
Log likelihood	35.32437	Durbin-Watson stat		1.980142

Table (A7.19)

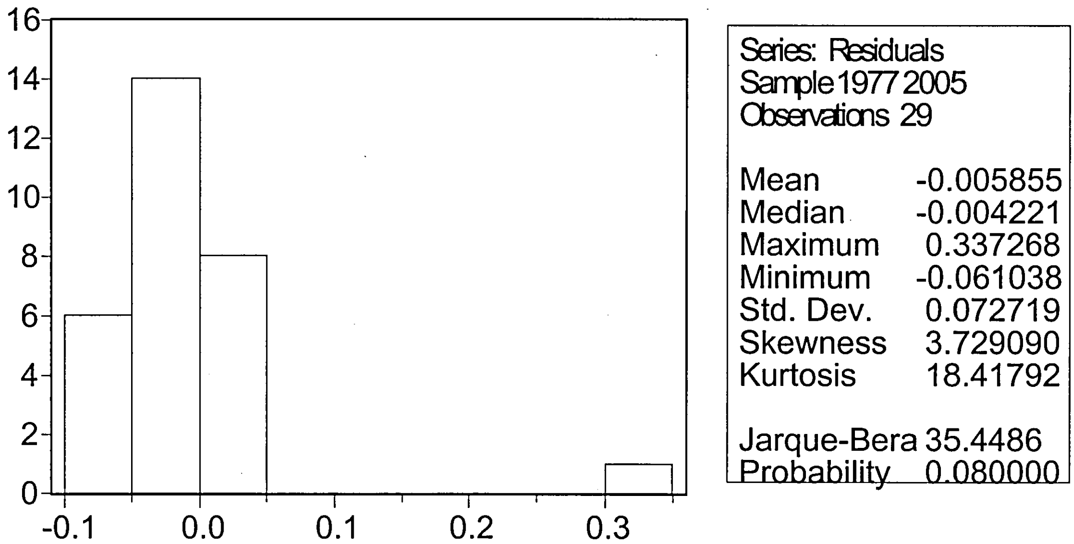
Test for Autocorrelation in the Residuals: the Serial Correlation Lagrange Multiplier (LM) Test with Zero Lags

Breusch-Godfrey Serial Correlation LM Test:				
F-statistic	0.069990	Probability		0.793521
Obs*R-squared	0.000000	Probability		1.000000
Test Equation:				
Dependent Variable: RESID				
Method: Least Squares				
Date: 05/08/07 Time: 12:30				
Presample missing value lagged residuals set to zero.				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.000660	0.008663	0.076197	0.9399
AR(1)	-0.015546	0.116899	-0.132985	0.8953
MA(1)	-0.002263	0.037908	-0.059695	0.9529
RESID(-1)	0.062898	0.237750	0.264555	0.7935
R-squared	-0.003904	Mean dependent var		-0.005855
Adjusted R-squared	-0.124373	S.D. dependent var		0.072719
S.E. of regression	0.077109	Akaike info criterion		-2.159748
Sum squared resid	0.148645	Schwarz criterion		-1.971155
Log likelihood	35.31634	Durbin-Watson stat		1.975150

From tables (A7.18) and (A7.19) we can notice that the p-value is greater than 0.05, so that we accept the null hypothesis of zero autocorrelation in the residuals. This is further evidence that the residuals are white noise.

Figure (A7. 6)

Normality of the Residuals



In figure (7,6) the p-value (=0.08) is higher than 0.05, so that we accept the null hypothesis of normality at the 5% significance level.

Table (A7.20)

Test if the Series is Stationary by using Unit Root Test with One Lag

ADF Test Statistic	-3.586900	1% Critical Value*		-2.6522
		5% Critical Value		-1.9540
		10% Critical Value		-1.6223
*MacKinnon critical values for rejection of hypothesis of a unit root.				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(RESID03)				
Method: Least Squares				
Date: 05/08/07 Time: 12:32				
Sample(adjusted): 1979 2005				
Included observations: 27 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID03(-1)	-0.995800	0.277621	-3.586900	0.0014
D(RESID03(-1))	0.034567	0.199717	0.173080	0.8640
R-squared	0.479791	Mean dependent var		0.002545
Adjusted R-squared	0.458982	S.D. dependent var		0.103914
S.E. of regression	0.076432	Akaike info criterion		-2.233632
Sum squared resid	0.146048	Schwarz criterion		-2.137644
Log likelihood	32.15403	Durbin-Watson stat		1.983894

Table (A7.21)

Test if the Series is Stationary by using Unit Root Test with Zero Lag

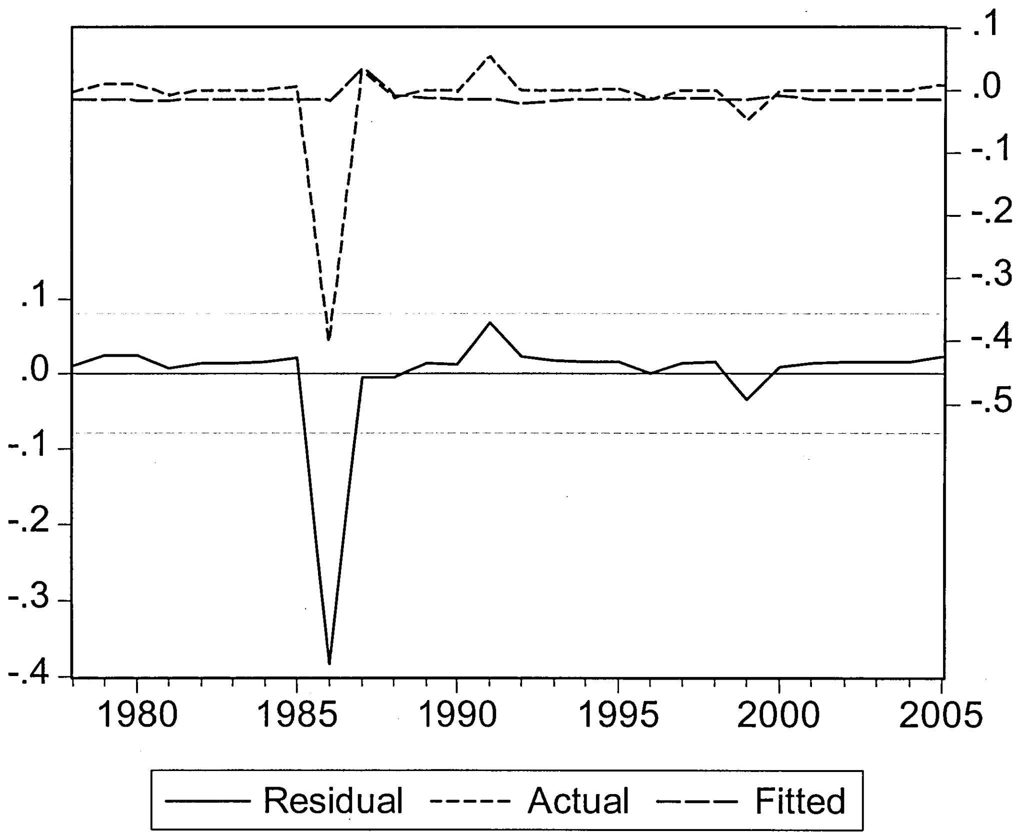
ADF Test Statistic	-4.970472	1% Critical Value*		-2.6486
		5% Critical Value		-1.9535
		10% Critical Value		-1.6221
*MacKinnon critical values for rejection of hypothesis of a unit root.				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(RESID03)				
Method: Least Squares				
Date: 05/08/07 Time: 12:33				
Sample(adjusted): 1978 2005				
Included observations: 28 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID03(-1)	-0.955086	0.192152	-4.970472	0.0000
R-squared	0.477325	Mean dependent var		0.003062
Adjusted R-squared	0.477325	S.D. dependent var		0.102008
S.E. of regression	0.073748	Akaike info criterion		-2.341269
Sum squared resid	0.146846	Schwarz criterion		-2.293690
Log likelihood	33.77776	Durbin-Watson stat		1.996135

As can be seen from tables (A7.20) and (A7.21), the ADF test statistic is -3.59 and -4.97 with a lag length of one and not included any lag respectively, which are much larger and more negative than any of the critical values. This is an indication that we can reject the null hypothesis of a unit root in the residual series. In other words, the residuals appear to be a stationary series. This is further evidence that the residuals are white noise

Residual Tests

Figure (A7.7)

Second Difference for Natural Logarithm for Water Demand for Industry ($\mathrm{dd}\ln W_I$)



The residuals do not seem to have a trend, they appear to have a mean value close to zero, and the variance of the series does not appear to change too much over time. There is no obvious trend in the series in the figure (A7.7) and it appears stationary

Table (A7.22)

Check the Size of the Differences between the Fitted and Actual Values

Obs	Actual	Fitted	Residual	Residual Plot
1978	-0.00334	-0.01428	0.01094	| . * . |
1979	0.00952	-0.01524	0.02476	| . |*. |
1980	0.00724	-0.01716	0.02440	| . |*. |
1981	-0.00987	-0.01723	0.00736	| . * . |
1982	-0.00112	-0.01506	0.01394	| . * . |
1983	-0.00051	-0.01573	0.01521	| . |*. |
1984	0.00028	-0.01597	0.01625	| . |*. |
1985	0.00498	-0.01611	0.02109	| . |*. |
1986	-0.39968	-0.01673	-0.38295	|* . | . |
1987	0.02874	0.03423	-0.00549	| . * . |
1988	-0.01398	-0.00941	-0.00457	| . * . |
1989	-3.0E-05	-0.01377	0.01374	| . * . |
1990	-0.00270	-0.01556	0.01285	| . * . |
1991	0.05259	-0.01569	0.06829	| . | * |
1992	-0.00016	-0.02265	0.02249	| . |*. |
1993	1.7E-05	-0.01742	0.01744	| . |*. |
1994	2.3E-05	-0.01626	0.01628	| . |*. |
1995	0.00040	-0.01613	0.01653	| . |*. |
1996	-0.01608	-0.01615	6.9E-05	| . * . |
1997	-2.5E-05	-0.01408	0.01405	| . * . |
1998	0.00033	-0.01568	0.01600	| . |*. |
1999	-0.04947	-0.01608	-0.03339	| .*| . |
2000	-2.7E-05	-0.00985	0.00982	| . * . |
2001	-3.4E-05	-0.01481	0.01478	| . * . |
2002	-4.3E-05	-0.01593	0.01588	| . |*. |
2003	6.5E-05	-0.01605	0.01612	| . |*. |
2004	-7.4E-05	-0.01610	0.01602	| . |*. |
2005	0.00697	-0.01609	0.02305	| . |*. |

Table (A7.23)

Check the Residual Correlogram for ARMA (3,1) if White Noise with Sixteen lags

Date: 05/08/07 Time: 12:39						
Sample: 1978 2005						
Included observations: 28						
Q-statistic probabilities adjusted for 2 ARMA term(s)						
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. | . |	. | . |	1	0.001	0.001	2.E-05	
. | . |	. | . |	2	0.002	0.002	9.E-05	
. | . |	. | . |	3	-0.046	-0.046	0.0717	0.789
. | . |	. | . |	4	-0.048	-0.048	0.1511	0.927
.*| . |	.*| . |	5	-0.169	-0.170	1.2000	0.753
.*| . |	.*| . |	6	-0.092	-0.099	1.5220	0.823
.*| . |	.*| . |	7	-0.079	-0.091	1.7696	0.880
.*| . |	.*| . |	8	-0.058	-0.087	1.9124	0.928
. | . |	. | . |	9	-0.017	-0.054	1.9245	0.964
. | . |	. | . |	10	0.026	-0.031	1.9552	0.982
. | . |	. | . |	11	0.001	-0.056	1.9553	0.992
. | . |	.*| . |	12	-0.003	-0.062	1.9557	0.997

Table (A7.24)

Check the Residual Correlogram for ARMA (3,1) if White Noise with Zero lag

Date: 05/08/07 Time: 12:40						
Sample: 1978 2005						
Included observations: 28						
Q-statistic probabilities adjusted for 2 ARMA term(s)						
Autocorrelation	Partial Correlation		AC	PAC	Q-Stat	Prob
. | . |	. | . |	1	0.001	0.001	2.E-05	
. | . |	. | . |	2	0.002	0.002	9.E-05	
. | . |	. | . |	3	-0.046	-0.046	0.0717	0.789
. | . |	. | . |	4	-0.048	-0.048	0.1511	0.927
.*| . |	.*| . |	5	-0.169	-0.170	1.2000	0.753
.*| . |	.*| . |	6	-0.092	-0.099	1.5220	0.823
.*| . |	.*| . |	7	-0.079	-0.091	1.7696	0.880
.*| . |	.*| . |	8	-0.058	-0.087	1.9124	0.928
. | . |	. | . |	9	-0.017	-0.054	1.9245	0.964
. | . |	. | . |	10	0.026	-0.031	1.9552	0.982
. | . |	. | . |	11	0.001	-0.056	1.9553	0.992
. | . |	.*| . |	12	-0.003	-0.062	1.9557	0.997

From tables (A7.23) and (A7.24) we can seen that the Q-statistic are significantly different from zero. For the model ARMA (1,1) all the residual correlations are within the bands and all of the Q-statistics have a p-value grater than 0.05. This means that at the 5% significance level we accept the null hypothesis that all the autocorrelation coefficients and jointly equal to zero. This result indicates that there is no autocorrelation in the residuals, so that they are likely to be white noise.

Table (A7.25)

Test for Autocorrelation in the Residuals: the Serial Correlation Lagrange Multiplier (LM) Test with Two Lags

Breusch-Godfrey Serial Correlation LM Test:				
F-statistic	0.057385	Probability		0.944365
Obs*R-squared	0.139021	Probability		0.932850
Test Equation:				
Dependent Variable: RESID				
Method: Least Squares				
Date: 05/08/07 Time: 12:41				
Presample missing value lagged residuals set to zero.				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.000170	0.013622	-0.012467	0.9902
AR(1)	-2.155967	11.91960	-0.180876	0.8580
MA(2)	-2.496496	8.107947	-0.307907	0.7609
RESID(-1)	2.153138	11.92077	0.180621	0.8582
RESID(-2)	2.225470	8.048187	0.276518	0.7846
R-squared	0.004965	Mean dependent var		3.46E-05
Adjusted R-squared	-0.168085	S.D. dependent var		0.076684
S.E. of regression	0.082878	Akaike info criterion		-1.982454
Sum squared resid	0.157983	Schwarz criterion		-1.744561
Log likelihood	32.75436	F-statistic		0.028691
Durbin-Watson stat	2.014675	Prob(F-statistic)		0.998289

Table (A7.26)

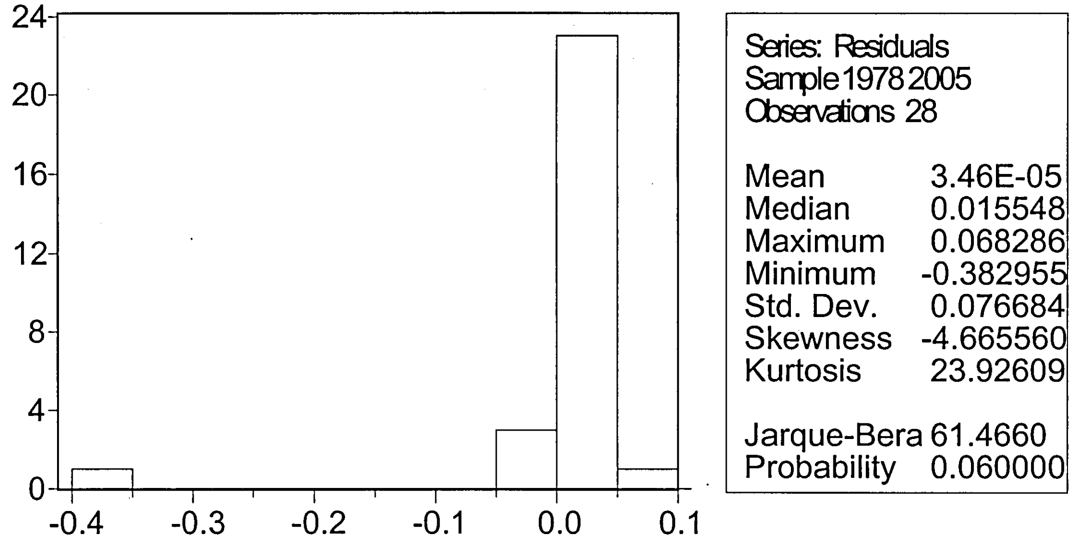
Test for Autocorrelation in the Residuals: the Serial Correlation Lagrange Multiplier (LM) Test with Zero Lags

Breusch-Godfrey Serial Correlation LM Test:				
F-statistic	0.039842	Probability		0.843472
Obs*R-squared	0.046399	Probability		0.829452
Test Equation:				
Dependent Variable: RESID				
Method: Least Squares				
Date: 05/08/07 Time: 12:42				
Presample missing value lagged residuals set to zero.				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	9.96E-05	0.013323	0.007479	0.9941
AR(1)	-2.329383	11.67182	-0.199573	0.8435
MA(2)	-0.294109	1.487819	-0.197678	0.8450
RESID(-1)	2.329846	11.67236	0.199604	0.8435
R-squared	0.001657	Mean dependent var		3.46E-05
Adjusted R-squared	-0.123136	S.D. dependent var		0.076684
S.E. of regression	0.081268	Akaike info criterion		-2.050564
Sum squared resid	0.158508	Schwarz criterion		-1.860249
Log likelihood	32.70789	F-statistic		0.013279
Durbin-Watson stat	1.997432	Prob(F-statistic)		0.997849

From tables (A7.25) and (A7.26) we can notice that the p-value is greater than 0.05, so that we accept the null hypothesis of zero autocorrelation in the residuals. This is further evidence that the residuals are white noise.

Figure (A7. 8)

Normality of the Residuals



In figure (A7.8) the p-value (=0.06) is higher than 0.05, so that we accept the null hypothesis of normality at the 5% significance level.

Table (A7.27)

Test if the Series is Stationary by using Unit Root Test with One Lag

ADF Test Statistic	-3.459527	1% Critical Value*		-2.6560
		5% Critical Value		-1.9546
		10% Critical Value		-1.6226
*MacKinnon critical values for rejection of hypothesis of a unit root.				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(RESID04)				
Method: Least Squares				
Date: 05/08/07 Time: 12:44				
Sample(adjusted): 1980 2005				
Included observations: 26 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID04(-1)	-0.999447	0.288897	-3.459527	0.0020
D(RESID04(-1))	-0.001549	0.204160	-0.007587	0.9940
R-squared	0.500630	Mean dependent var		-6.57E-05
Adjusted R-squared	0.479822	S.D. dependent var		0.112512
S.E. of regression	0.081147	Akaike info criterion		-2.111294
Sum squared resid	0.158038	Schwarz criterion		-2.014518
Log likelihood	29.44683	Durbin-Watson stat		2.000378

Table (A7.28)

Test if the Series is Stationary by using Unit Root with Zero Lag

ADF Test Statistic	-5.088766	1% Critical Value*		-2.6522
		5% Critical Value		-1.9540
		10% Critical Value		-1.6223
*MacKinnon critical values for rejection of hypothesis of a unit root.				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(RESID04)				
Method: Least Squares				
Date: 05/08/07 Time: 12:45				
Sample(adjusted): 1979 2005				
Included observations: 27 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESID04(-1)	-0.999286	0.196371	-5.088766	0.0000
R-squared	0.498985	Mean dependent var		0.000449
Adjusted R-squared	0.498985	S.D. dependent var		0.110360
S.E. of regression	0.078115	Akaike info criterion		-2.224932
Sum squared resid	0.158651	Schwarz criterion		-2.176938
Log likelihood	31.03659	Durbin-Watson stat		1.996208

As can be seen from tables (A7.27) and (A7.28), the ADF test statistic is -3.46 and -5.09 with a lag length of one and not included any leg respectively, which are much larger and more negative than any of the critical values. This is an indication that we can reject the null hypothesis of a unit root in the residual series. In other words, the residuals appear to be a stationary series. This is further evidence that the residuals are white noise

Forecasting Time Series for First Difference for Natural Logarithm of Total Water Demand ($d\ln W$)

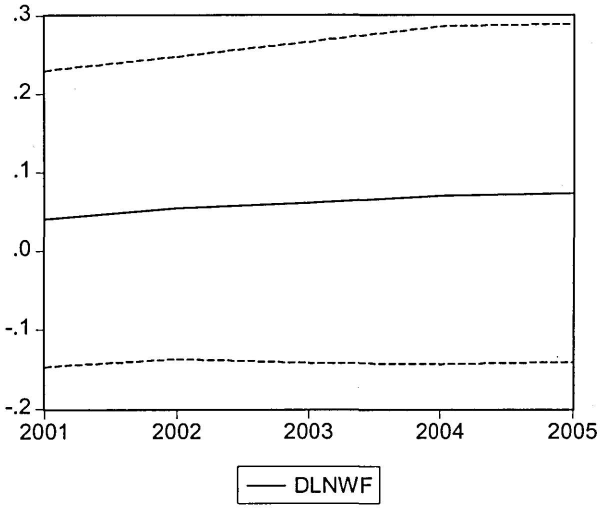
Table (A7.29)

Estimate ARMA (3,1,1) 1975-2000

Dependent Variable: DLNW				
Method: Least Squares				
Date: 05/15/07 Time: 10:26				
Sample(adjusted): 1979 2000				
Included observations: 22 after adjusting endpoints				
Failure to improve SSR after 16 iterations				
Backcast: 1978				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.068588	0.016248	4.221347	0.0006
AR(1)	0.783416	0.206944	3.785647	0.0015
AR(2)	0.529500	0.242812	2.180699	0.0435
AR(3)	-0.527361	0.193630	-2.723553	0.0144
MA(1)	-0.997408	0.172261	-5.790088	0.0000
R-squared	0.538950	Mean dependent var		0.102519
Adjusted R-squared	0.430468	S.D. dependent var		0.124738
S.E. of regression	0.094136	Akaike info criterion		-1.691429
Sum squared resid	0.150648	Schwarz criterion		-1.443464
Log likelihood	23.60571	F-statistic		4.968087
Durbin-Watson stat	2.172632	Prob(F-statistic)		0.007737
Inverted AR Roots	.78 -.27i	.78+.27i	-.78	
Inverted MA Roots	1.00			

Dynamic Forecast

Figure (A7.9)



Forecast: DLNWF
Actual: DLNW
Forecast sample: 2001 2005
Included observations: 5

Root Mean Squared Error	0.037349
Mean Absolute Error	0.036992
Mean Abs. Percent Error	275.4052
Theil Inequality Coefficient	0.430517
Bias Proportion	0.980998
Variance Proportion	0.002863
Covariance Proportion	0.016139

Table (A7. 30)

Obs	DLNW	DLNWF
1975	NA	NA
1976	0.031403	0.031403
1977	0.095424	0.095424
1978	0.102827	0.102827
1979	0.110301	0.110301
1980	0.327445	0.327445
1981	0.045999	0.045999
1982	0.411448	0.411448
1983	0.097740	0.097740
1984	0.387358	0.387358
1985	0.090932	0.090932
1986	0.031859	0.031859
1987	0.032324	0.032324
1988	0.032085	0.032085
1989	-0.022904	-0.022904
1990	-0.000663	-0.000663
1991	0.101307	0.101307
1992	0.147576	0.147576
1993	0.126081	0.126081
1994	0.127271	0.127271
1995	0.165149	0.165149
1996	-0.045881	-0.045881
1997	0.019177	0.019177
1998	0.019323	0.019323
1999	0.018096	0.018096
2000	0.033395	0.033395
2001	0.004308	0.040833
2002	0.026219	0.054836
2003	0.026456	0.061678
2004	0.027061	0.070530
2005	0.032576	0.073703

Figure (A7.10)

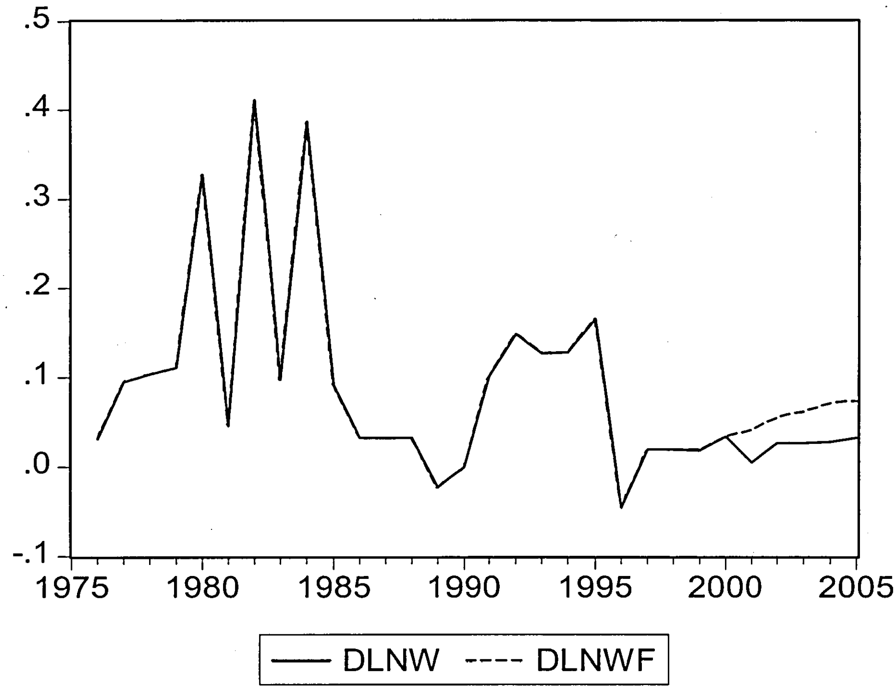
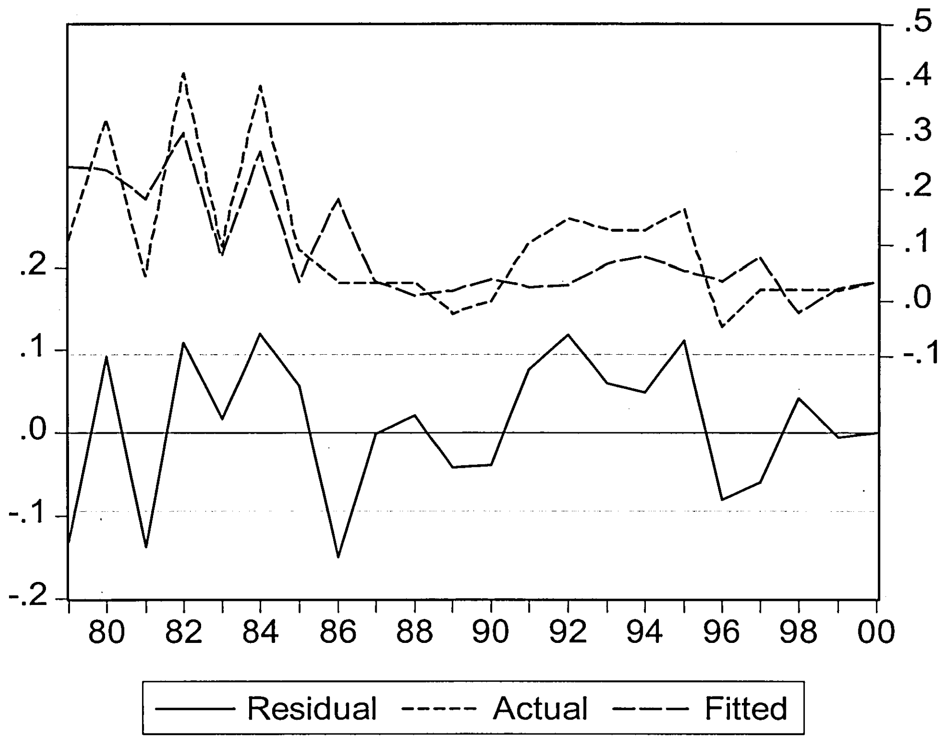
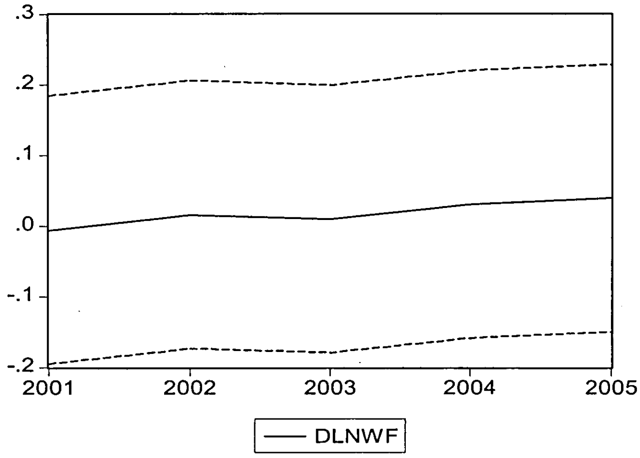


Figure (A7.11)



Static Forecast

Figure (A7.12)



Forecast: DLNWF	
Actual: DLNW	
Forecast sample: 2001 2005	
Included observations: 5	
Root Mean Squared Error	0.010481
Mean Absolute Error	0.009470
Mean Abs. Percent Error	74.88319
Theil Inequality Coefficient	0.213172
Bias Proportion	0.272313
Variance Proportion	0.333671
Covariance Proportion	0.394016

Table (A7. 31)

obs	DLNW	DLNWF
1975	NA	NA
1976	0.031403	0.031403
1977	0.095424	0.095424
1978	0.102827	0.102827
1979	0.110301	0.110301
1980	0.327445	0.327445
1981	0.045999	0.045999
1982	0.411448	0.411448
1983	0.097740	0.097740
1984	0.387358	0.387358
1985	0.090932	0.090932
1986	0.031859	0.031859
1987	0.032324	0.032324
1988	0.032085	0.032085
1989	-0.022904	-0.022904
1990	-0.000663	-0.000663
1991	0.101307	0.101307
1992	0.147576	0.147576
1993	0.126081	0.126081
1994	0.127271	0.127271
1995	0.165149	0.165149
1996	-0.045881	-0.045881
1997	0.019177	0.019177
1998	0.019323	0.019323
1999	0.018096	0.018096
2000	0.033395	0.033395
2001	0.004308	-0.005992
2002	0.026219	0.015949
2003	0.026456	0.009676
2004	0.027061	0.030309
2005	0.032576	0.039329

Actual and Forecast Values

Figure (A7.13)

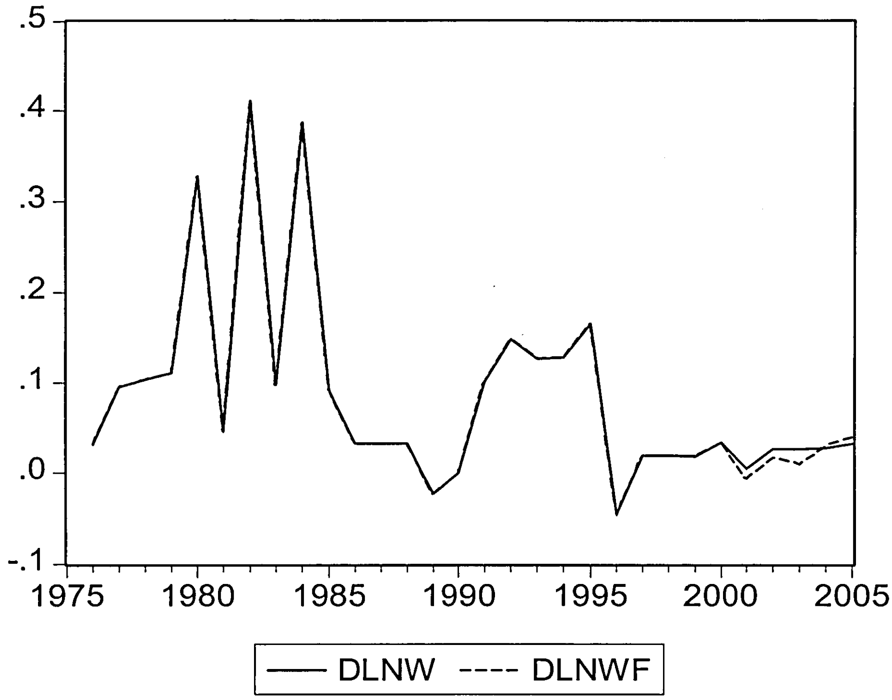


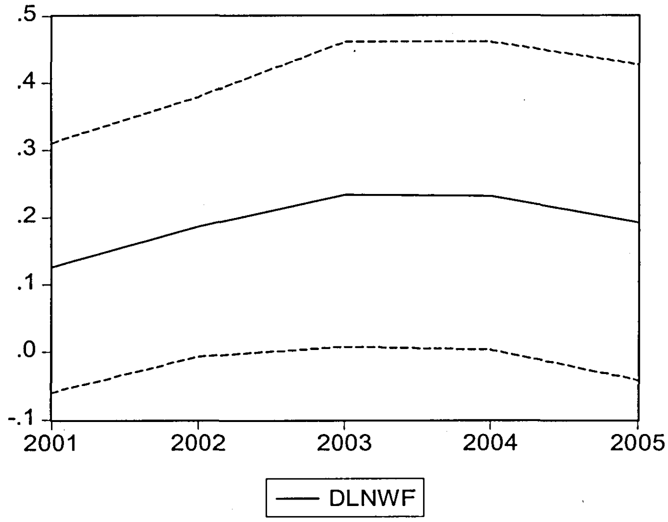
Table (A7.32)

Estimate ARMA (3,1, 2) 1975-2000

Dependent Variable: DLNW				
Method: Least Squares				
Date: 05/15/07 Time: 10:39				
Sample(adjusted): 1979 2000				
Included observations: 22 after adjusting endpoints				
Convergence achieved after 26 iterations				
Backcast: 1977 1978				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.105848	0.023091	4.583979	0.0003
AR(1)	1.075901	0.207188	5.192877	0.0001
AR(2)	-0.016971	0.340225	-0.049882	0.9608
AR(3)	-0.577884	0.221542	-2.608460	0.0190
MA(1)	-1.366467	0.073421	-18.61140	0.0000
MA(2)	0.972943	0.082426	11.80389	0.0000
R-squared	0.577741	Mean dependent var		0.102519
Adjusted R-squared	0.445785	S.D. dependent var		0.124738
S.E. of regression	0.092862	Akaike info criterion		-1.688407
Sum squared resid	0.137973	Schwarz criterion		-1.390850
Log likelihood	24.57248	F-statistic		4.378284
Durbin-Watson stat	1.902538	Prob(F-statistic)		0.010568
Inverted AR Roots	.83 -.55i	.83+.55i	-.58	
Inverted MA Roots	.68+.71i	.68 -.71i		

Dynamic Forecast

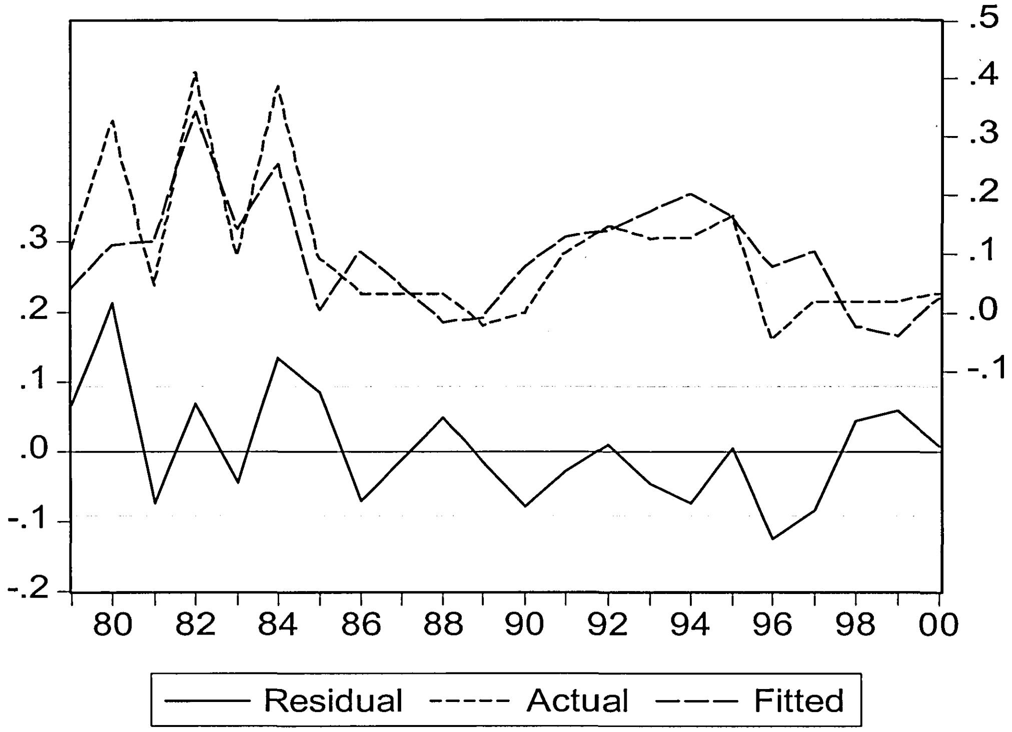
Figure (A7.14)



Forecast: DLNWF
Actual: DLNW
Forecast sample: 2001 2005
Included observations: 5

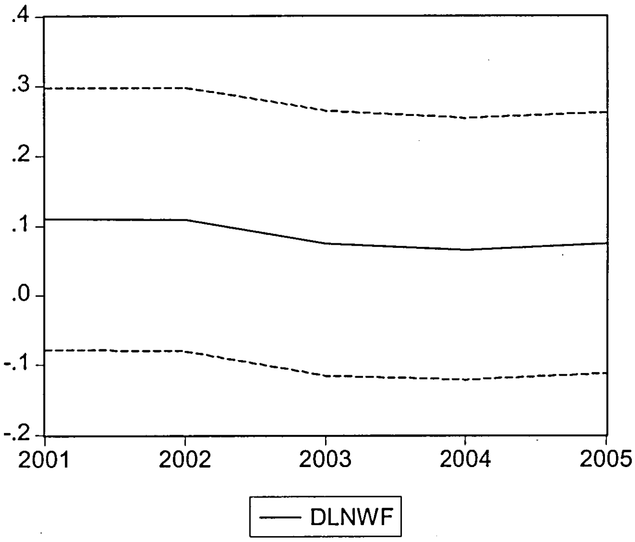
Root Mean Squared Error	0.173610
Mean Absolute Error	0.170584
Mean Abs. Percent Error	1090.076
Theil Inequality Coefficient	0.777886
Bias Proportion	0.965451
Variance Proportion	0.029237
Covariance Proportion	0.005312

Figure (A7.15)



Static Forecasting

Figure (A7.16)



Forecast: DLNWF
Actual: DLNW
Forecast sample: 2001 2005
Included observations: 5

Root Mean Squared Error	0.068414
Mean Absolute Error	0.063146
Mean Abs. Percent Error	641.8395
Theil Inequality Coefficient	0.601196
Bias Proportion	0.851921
Variance Proportion	0.017545
Covariance Proportion	0.130535

Forecasting Time Series for First Difference for Natural Logarithm of Water Demand for Agriculture ($d\ln W_A$)

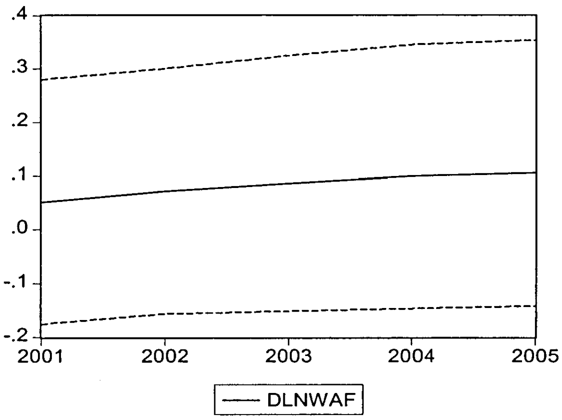
Table (A7.33)

Estimate ARMA (3,1) 1975-2000

Dependent Variable: DLNWA				
Method: Least Squares				
Date: 05/15/07 Time: 11:52				
Sample(adjusted): 1979 2000				
Included observations: 22 after adjusting endpoints				
Convergence achieved after 8 iterations				
Backcast: 1978				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.083030	0.014469	5.738291	0.0000
AR(1)	0.949202	0.212095	4.475354	0.0003
AR(2)	0.344662	0.282110	1.221728	0.2385
AR(3)	-0.532203	0.197510	-2.694566	0.0153
MA(1)	-0.996940	0.116256	-8.575375	0.0000
R-squared	0.496388	Mean dependent var		0.112752
Adjusted R-squared	0.377892	S.D. dependent var		0.144665
S.E. of regression	0.114103	Akaike info criterion		-1.306718
Sum squared resid	0.221331	Schwarz criterion		-1.058753
Log likelihood	19.37389	F-statistic		4.189042
Durbin-Watson stat	2.302913	Prob(F-statistic)		0.015326
Inverted AR Roots	.82+.33i	.82 -.33i	-.69	
Inverted MA Roots	1.00			

Dynamic Forecast

Figure (A7.17)



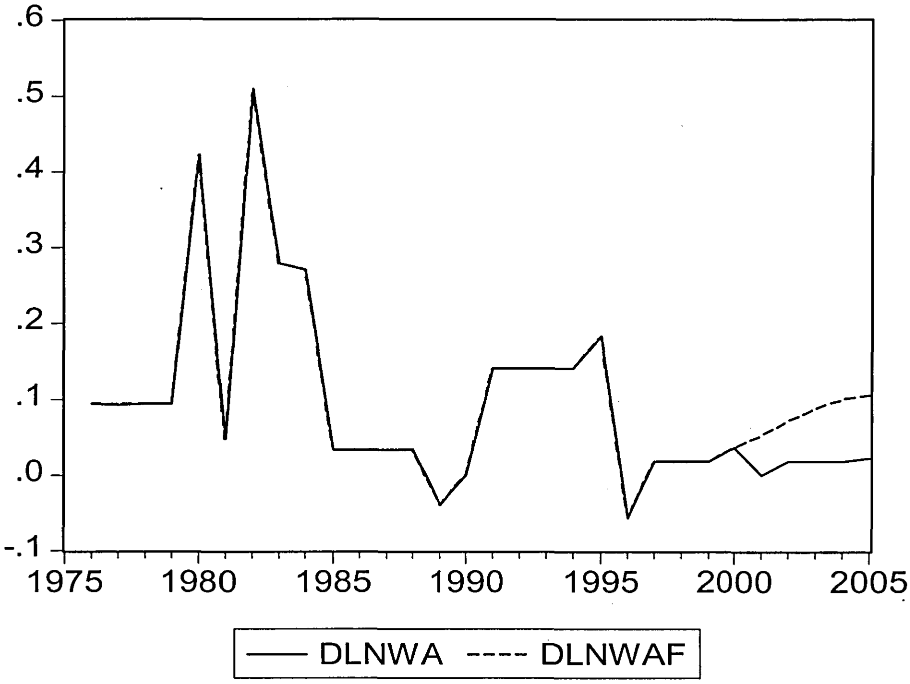
Forecast: DLNWAF
Actual: DLNWA
Forecast sample: 2001 2005
Included observations: 5

Root Mean Squared Error	0.068819
Mean Absolute Error	0.067506
Mean Abs. Percent Error	301.6767
Theil Inequality Coefficient	0.674515
Bias Proportion	0.962201
Variance Proportion	0.029149
Covariance Proportion	0.008650

Table (A7.34)

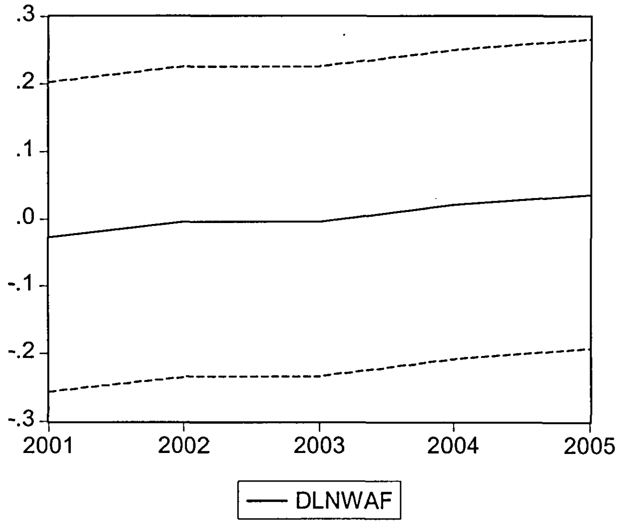
Obs	DLNWA	DLNWAF
1975	NA	NA
1976	0.093473	0.093473
1977	0.091650	0.091650
1978	0.093447	0.093447
1979	0.093470	0.093470
1980	0.421576	0.421576
1981	0.046744	0.046744
1982	0.508513	0.508513
1983	0.277632	0.277632
1984	0.269117	0.269117
1985	0.032436	0.032436
1986	0.032498	0.032498
1987	0.032466	0.032466
1988	0.032467	0.032467
1989	-0.039843	-0.039843
1990	0.000000	0.000000
1991	0.139762	0.139762
1992	0.139762	0.139762
1993	0.139761	0.139761
1994	0.139760	0.139760
1995	0.181923	0.181923
1996	-0.056491	-0.056491
1997	0.017840	0.017840
1998	0.017840	0.017840
1999	0.017841	0.017841
2000	0.035477	0.035477
2001	0.000000	0.051400
2002	0.018041	0.071311
2003	0.017771	0.086313
2004	0.017909	0.098940
2005	0.022213	0.105500

Figure (A7.18)



Static Forecast

Figure (A7.19)



Forecast: DLNWAF
Actual: DLNWA
Forecast sample: 2001 2005
Included observations: 5

Root Mean Squared Error	0.019763
Mean Absolute Error	0.017747
Mean Abs. Percent Error	65.69785
Theil Inequality Coefficient	0.501076
Bias Proportion	0.318876
Variance Proportion	0.519143
Covariance Proportion	0.161981

Table (A7.35)

Obs	DLNWA	DLNWAF
1975	NA	NA
1976	0.093473	0.093473
1977	0.091650	0.091650
1978	0.093447	0.093447
1979	0.093470	0.093470
1980	0.421576	0.421576
1981	0.046744	0.046744
1982	0.508513	0.508513
1983	0.277632	0.277632
1984	0.269117	0.269117
1985	0.032436	0.032436
1986	0.032498	0.032498
1987	0.032466	0.032466
1988	0.032467	0.032467
1989	-0.039843	-0.039843
1990	0.000000	0.000000
1991	0.139762	0.139762
1992	0.139762	0.139762
1993	0.139761	0.139761
1994	0.139760	0.139760
1995	0.181923	0.181923
1996	-0.056491	-0.056491
1997	0.017840	0.017840
1998	0.017840	0.017840
1999	0.017841	0.017841
2000	0.035477	0.035477
2001	0.000000	-0.027242
2002	0.018041	-0.004637
2003	0.017771	-0.004576
2004	0.017909	0.020597
2005	0.022213	0.035992

Figure (A7.20)

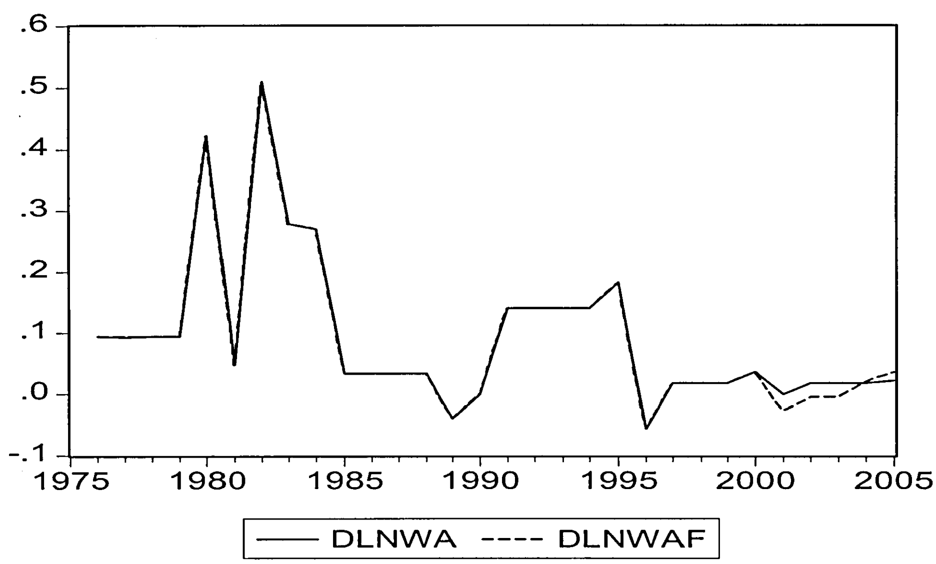


Figure (A7.21)

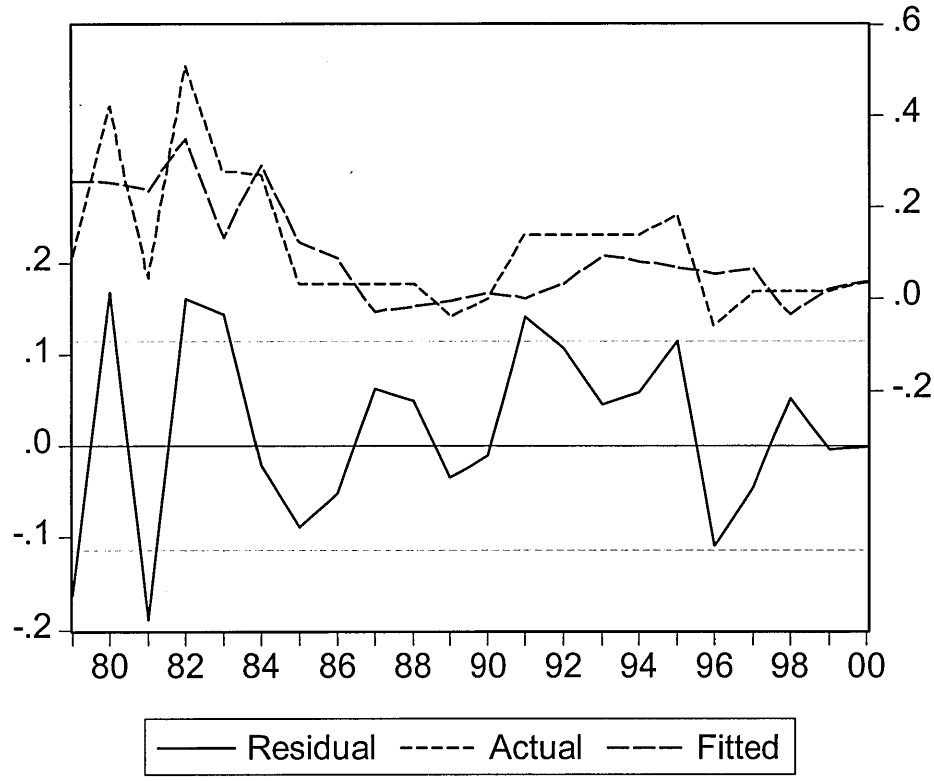


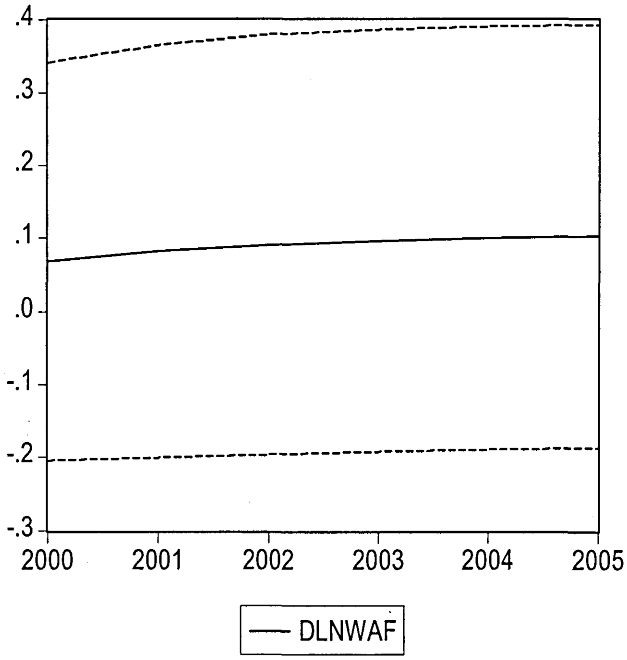
Table (A7.36)

Estimate ARMA (1,1, 1) 1975-2000

Dependent Variable: DLNWA				
Method: Least Squares				
Date: 05/15/07 Time: 12:05				
Sample(adjusted): 1977 2000				
Included observations: 24 after adjusting endpoints				
Convergence achieved after 16 iterations				
Backcast: 1976				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.107580	0.052155	2.062697	0.0517
AR(1)	0.655907	0.487124	1.346490	0.1925
MA(1)	-0.385207	0.584122	-0.659463	0.5168
R-squared	0.109169	Mean dependent var		0.111069
Adjusted R-squared	0.024328	S.D. dependent var		0.138350
S.E. of regression	0.136657	Akaike info criterion		-1.026220
Sum squared resid	0.392177	Schwarz criterion		-0.878963
Log likelihood	15.31464	F-statistic		1.286744
Durbin-Watson stat	2.242251	Prob(F-statistic)		0.297066
Inverted AR Roots	.66			
Inverted MA Roots	.39			

Dynamic Forecast

Figure (A7.22)

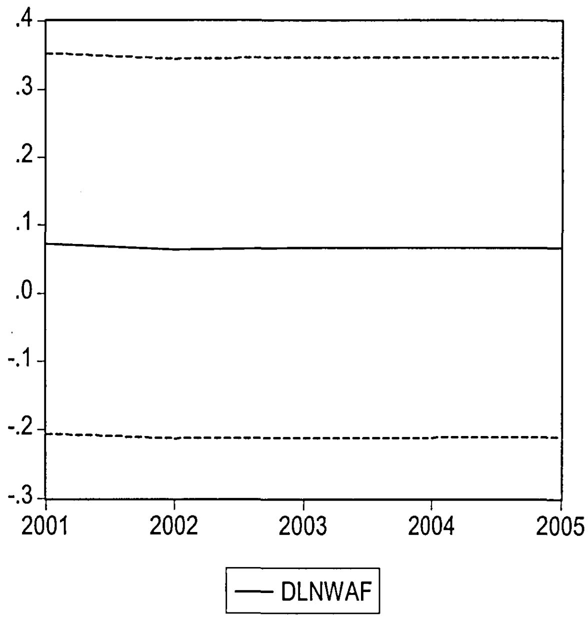


Forecast: DLNWAF
Actual: DLNWA
Forecast sample: 2000 2005
Included observations: 6

Root Mean Squared Error	0.073648
Mean Absolute Error	0.071517
Mean Abs. Percent Error	293.5714
Theil Inequality Coefficient	0.656768
Bias Proportion	0.942986
Variance Proportion	0.000430
Covariance Proportion	0.056584

Static Forecast

Figure (A7.23)



Forecast: DLNWAF
Actual: DLNWA
Forecast sample: 2001 2005
Included observations: 5

Root Mean Squared Error	0.053889
Mean Absolute Error	0.052932
Mean Abs. Percent Error	204.2524
Theil Inequality Coefficient	0.632281
Bias Proportion	0.964794
Variance Proportion	0.009211
Covariance Proportion	0.025995

Forecasting Time Series for First Difference for Natural Logarithm of Water Demand for Domestic use ($d\ln W_D$)

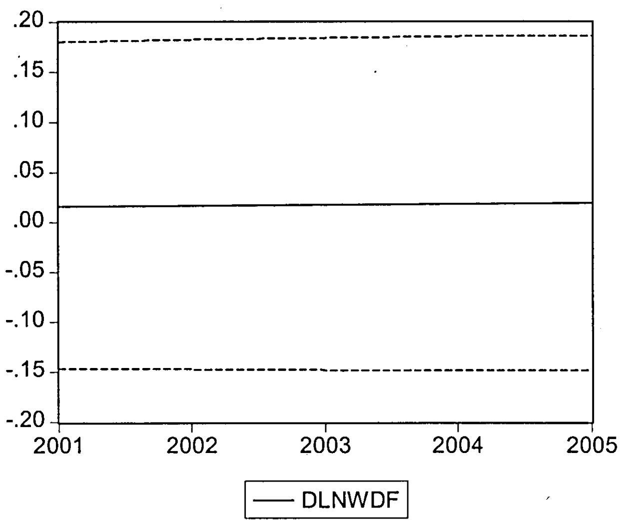
Table (A7.37)

Estimate ARMA (1,1,1) 1975-2000

Dependent Variable: DLNWD				
Method: Least Squares				
Date: 05/28/07 Time: 14:01				
Sample(adjusted): 1977 2000				
Included observations: 24 after adjusting endpoints				
Convergence achieved after 21 iterations				
Backcast: 1976				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.021812	0.030807	0.708036	0.4867
AR(1)	0.858271	0.132732	6.466202	0.0000
MA(1)	-0.996977	0.107090	-9.309724	0.0000
R-squared	0.197853	Mean dependent var		0.059121
Adjusted R-squared	0.121458	S.D. dependent var		0.087136
S.E. of regression	0.081673	Akaike info criterion		-2.055708
Sum squared resid	0.140081	Schwarz criterion		-1.908451
Log likelihood	27.66849	F-statistic		2.589870
Durbin-Watson stat	2.087616	Prob(F-statistic)		0.098779
Inverted AR Roots	.86			
Inverted MA Roots	1.00			

Dynamic Forecast

Figure (A7.24)

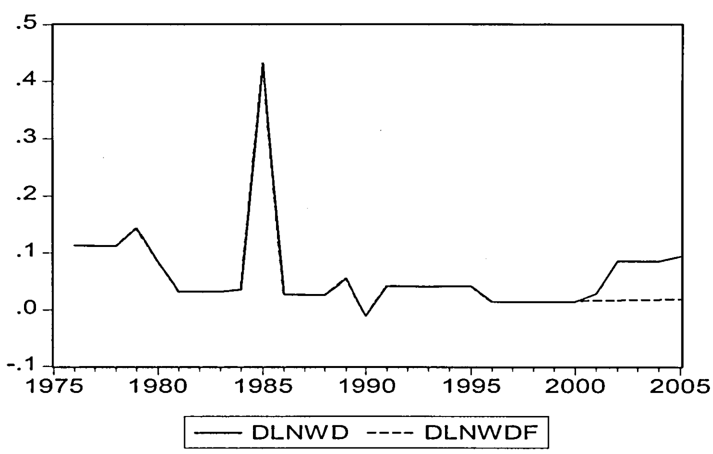


Forecast: DLNWDF	
Actual: DLNWD	
Forecast sample: 2001 2005	
Included observations: 5	
Root Mean Squared Error	0.062616
Mean Absolute Error	0.058314
Mean Abs. Percent Error	72.63897
Theil Inequality Coefficient	0.646157
Bias Proportion	0.867292
Variance Proportion	0.130708
Covariance Proportion	0.001999

Table (A7. 38)

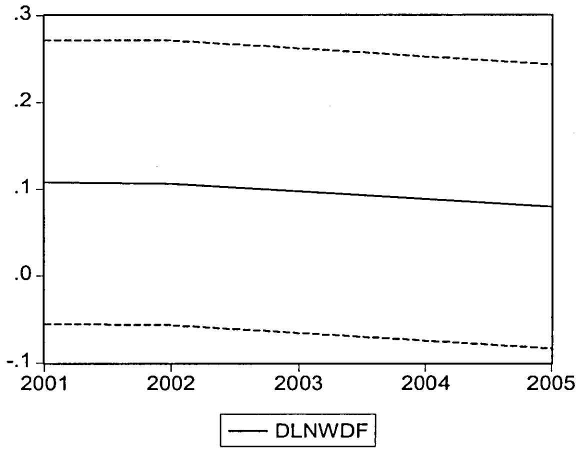
Obs	DLNWD	DLNWDF
1975	NA	NA
1976	0.112921	0.112921
1977	0.112435	0.112435
1978	0.112453	0.112453
1979	0.143128	0.143128
1980	0.083784	0.083784
1981	0.032476	0.032476
1982	0.032453	0.032453
1983	0.032441	0.032441
1984	0.035930	0.035930
1985	0.431593	0.431593
1986	0.027026	0.027026
1987	0.026639	0.026639
1988	0.026652	0.026652
1989	0.054857	0.054857
1990	-0.011561	-0.011561
1991	0.041811	0.041811
1992	0.042102	0.042102
1993	0.041140	0.041140
1994	0.042115	0.042115
1995	0.041923	0.041923
1996	0.013903	0.013903
1997	0.013896	0.013896
1998	0.013904	0.013904
1999	0.013910	0.013910
2000	0.013895	0.013895
2001	0.029175	0.016085
2002	0.085256	0.016897
2003	0.085266	0.017594
2004	0.085257	0.018192
2005	0.094086	0.018705

Figure (A7.25)



Static Forecast

Figure (A7.26)



Forecast: DLNWDF	
Actual: DLNWD	
Forecast sample: 2001 2005	
Included observations: 5	
Root Mean Squared Error	0.037372
Mean Absolute Error	0.025911
Mean Abs. Percent Error	65.46572
Theil Inequality Coefficient	0.212580
Bias Proportion	0.286424
Variance Proportion	0.116587
Covariance Proportion	0.596988

Table (A7.39)

Obs	DLNWD	DLNWDF
1975	NA	NA
1976	0.112921	0.112921
1977	0.112435	0.112435
1978	0.112453	0.112453
1979	0.143128	0.143128
1980	0.083784	0.083784
1981	0.032476	0.032476
1982	0.032453	0.032453
1983	0.032441	0.032441
1984	0.035930	0.035930
1985	0.431593	0.431593
1986	0.027026	0.027026
1987	0.026639	0.026639
1988	0.026652	0.026652
1989	0.054857	0.054857
1990	-0.011561	-0.011561
1991	0.041811	0.041811
1992	0.042102	0.042102
1993	0.041140	0.041140
1994	0.042115	0.042115
1995	0.041923	0.041923
1996	0.013903	0.013903
1997	0.013896	0.013896
1998	0.013904	0.013904
1999	0.013910	0.013910
2000	0.013895	0.013895
2001	0.029175	0.107679
2002	0.085256	0.106399
2003	0.085266	0.097343
2004	0.085257	0.088313
2005	0.094086	0.079312

Figure (A7.27)

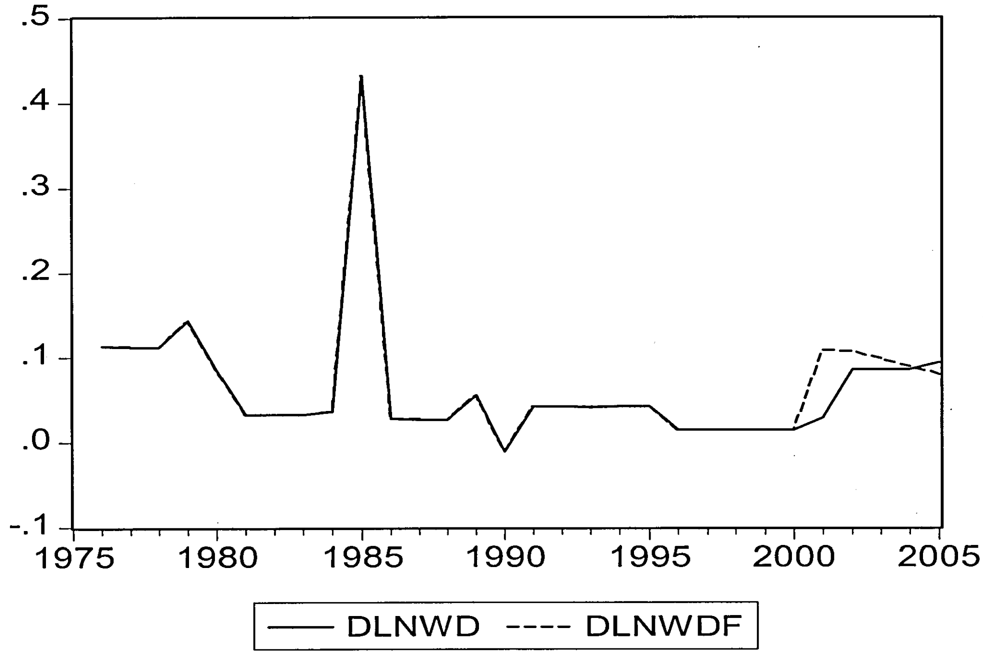


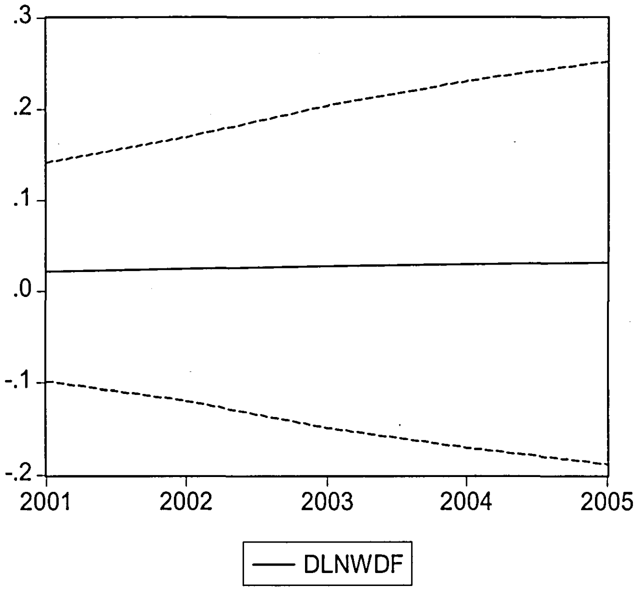
Table (A7. 40)

Estimate ARMA (1,1, 2) 1975-2000

Dependent Variable: DLNWD				
Method: Least Squares				
Date: 05/15/07 Time: 12:23				
Sample(adjusted): 1977 2000				
Included observations: 24 after adjusting endpoints				
Convergence achieved after 60 iterations				
Backcast: OFF (Roots of MA process too large)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.069887	0.127005	0.550267	0.5882
AR(1)	0.944575	0.189786	4.977061	0.0001
MA(1)	-1.614977	0.507316	-3.183373	0.0047
MA(2)	-0.211460	0.443064	-0.477268	0.6383
R-squared	0.587845	Mean dependent var		0.059121
Adjusted R-squared	0.526022	S.D. dependent var		0.087136
S.E. of regression	0.059990	Akaike info criterion		-2.638267
Sum squared resid	0.071976	Schwarz criterion		-2.441925
Log likelihood	35.65921	F-statistic		9.508481
Durbin-Watson stat	2.574712	Prob(F-statistic)		0.000414
Inverted AR Roots	.94			
Inverted MA Roots	1.74	-.12		
	Estimated MA process is noninvertible			

Dynamic Forecast

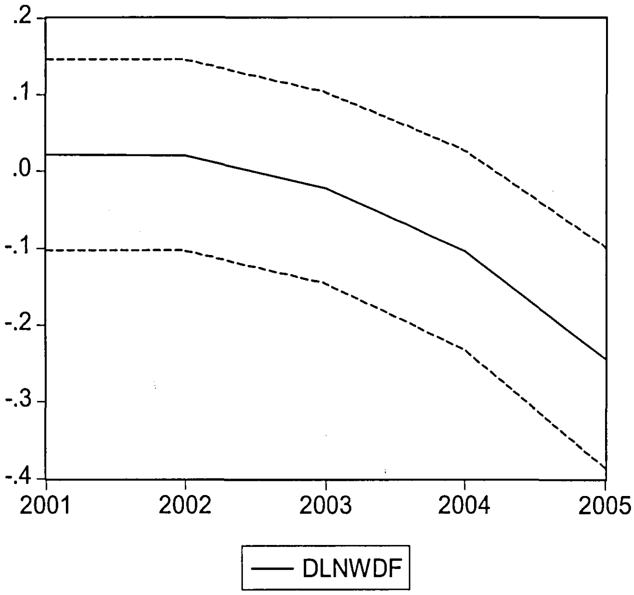
Figure (A7.28)



Forecast: DLNWDF	
Actual: DLNWD	
Forecast sample: 2001 2005	
Included observations: 5	
Root Mean Squared Error	0.052860
Mean Absolute Error	0.048645
Mean Abs. Percent Error	59.07893
Theil Inequality Coefficient	0.494989
Bias Proportion	0.846876
Variance Proportion	0.142327
Covariance Proportion	0.010797

Static Forecast

Figure (A7.29)



Forecast: DLNWDF	
Actual: DLNWD	
Forecast sample: 2001 2005	
Included observations: 5	
Root Mean Squared Error	0.182160
Mean Absolute Error	0.141569
Mean Abs. Percent Error	161.9999
Theil Inequality Coefficient	0.915135
Bias Proportion	0.603991
Variance Proportion	0.175960
Covariance Proportion	0.220048

Forecasting Time Series for Second Difference for Natural Logarithm of Water Demand for Industry (dd $\ln W_I$)

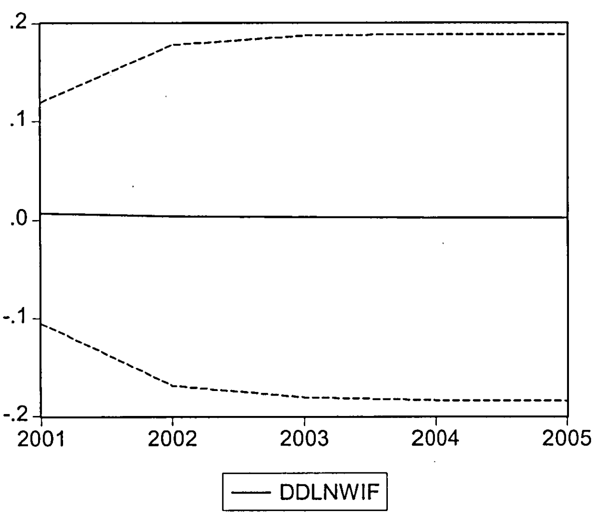
Table (A7.41)

Estimate ARMA (1,1,1) 1975-2000

Dependent Variable: DDLNWI				
Method: Least Squares				
Date: 05/15/07. Time: 12:33				
Sample(adjusted): 1978 2000				
Included observations: 23 after adjusting endpoints				
Convergence achieved after 201 iterations				
Backcast: OFF (Roots of MA process too large)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.001403	0.005960	0.235370	0.8163
AR(1)	0.463058	0.197991	2.338786	0.0298
MA(1)	-1.640715	0.302423	-5.425233	0.0000
R-squared	0.604937	Mean dependent var		-0.017082
Adjusted R-squared	0.565431	S.D. dependent var		0.085230
S.E. of regression	0.056185	Akaike info criterion		-2.799209
Sum squared resid	0.063136	Schwarz criterion		-2.651101
Log likelihood	35.19090	F-statistic		15.31242
Durbin-Watson stat	1.831002	Prob(F-statistic)		0.000093
Inverted AR Roots	.46			
Inverted MA Roots	1.64			
	Estimated MA process is noninvertible			

Dynamic Forecast

Figure (A7.30)

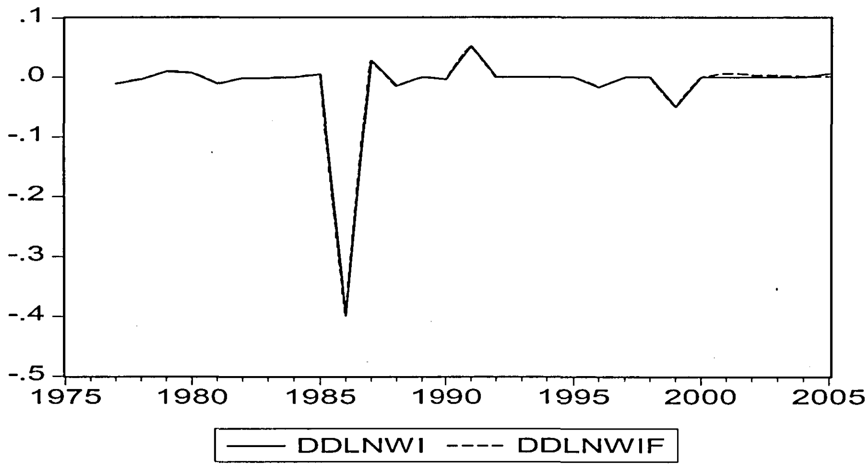


Forecast: DDLNWIF	
Actual: DDLNWI	
Forecast sample: 2001 2005	
Included observations: 5	
Root Mean Squared Error	0.004412
Mean Absolute Error	0.004054
Mean Abs. Percent Error	6965.364
Theil Inequality Coefficient	0.641062
Bias Proportion	0.190195
Variance Proportion	0.049447
Covariance Proportion	0.760359

Table (A7.42)

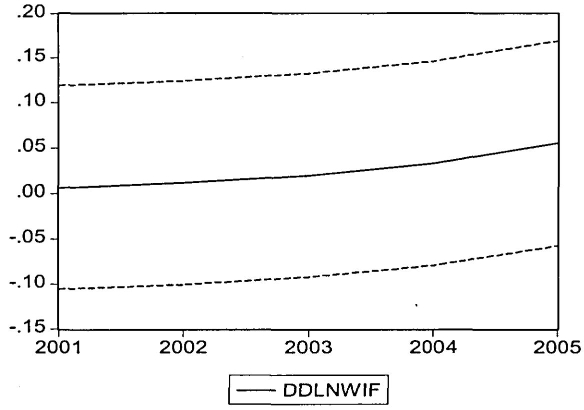
obs	DDLNWI	DDLNWIF
1975	NA	NA
1976	NA	NA
1977	-0.011012	-0.011012
1978	-0.003341	-0.003341
1979	0.009520	0.009520
1980	0.007236	0.007236
1981	-0.009873	-0.009873
1982	-0.001123	-0.001123
1983	-0.000515	-0.000515
1984	0.000279	0.000279
1985	0.004981	0.004981
1986	-0.399682	-0.399682
1987	0.028737	0.028737
1988	-0.013975	-0.013975
1989	-3.04E-05	-3.04E-05
1990	-0.002703	-0.002703
1991	0.052594	0.052594
1992	-0.000162	-0.000162
1993	1.71E-05	1.71E-05
1994	2.26E-05	2.26E-05
1995	0.000401	0.000401
1996	-0.016081	-0.016081
1997	-2.52E-05	-2.52E-05
1998	0.000326	0.000326
1999	-0.049473	-0.049473
2000	-2.71E-05	-2.71E-05
2001	-3.43E-05	0.006607
2002	-4.31E-05	0.003813
2003	6.54E-05	0.002519
2004	-7.44E-05	0.001920
2005	0.006966	0.001642

Figure (A7.31)



Static Forecast

Figure (A7. 32)



Forecast: DDLNWIF
Actual: DDLNWI
Forecast sample: 2001 2005
Included observations: 5

Root Mean Squared Error	0.028437
Mean Absolute Error	0.024012
Mean Abs. Percent Error	24470.19
Theil Inequality Coefficient	0.836782
Bias Proportion	0.712996
Variance Proportion	0.269498
Covariance Proportion	0.017506

Table (A7.43)

Obs	DDLNWI	DDLNWIF
1975	NA	NA
1976	NA	NA
1977	-0.011012	-0.011012
1978	-0.003341	-0.003341
1979	0.009520	0.009520
1980	0.007236	0.007236
1981	-0.009873	-0.009873
1982	-0.001123	-0.001123
1983	-0.000515	-0.000515
1984	0.000279	0.000279
1985	0.004981	0.004981
1986	-0.399682	-0.399682
1987	0.028737	0.028737
1988	-0.013975	-0.013975
1989	-3.04E-05	-3.04E-05
1990	-0.002703	-0.002703
1991	0.052594	0.052594
1992	-0.000162	-0.000162
1993	1.71E-05	1.71E-05
1994	2.26E-05	2.26E-05
1995	0.000401	0.000401
1996	-0.016081	-0.016081
1997	-2.52E-05	-2.52E-05
1998	0.000326	0.000326
1999	-0.049473	-0.049473
2000	-2.71E-05	-2.71E-05
2001	-3.43E-05	0.006607
2002	-4.31E-05	0.011633
2003	6.54E-05	0.019891
2004	-7.44E-05	0.033312
2005	0.006966	0.055496

Figure (A7.33)

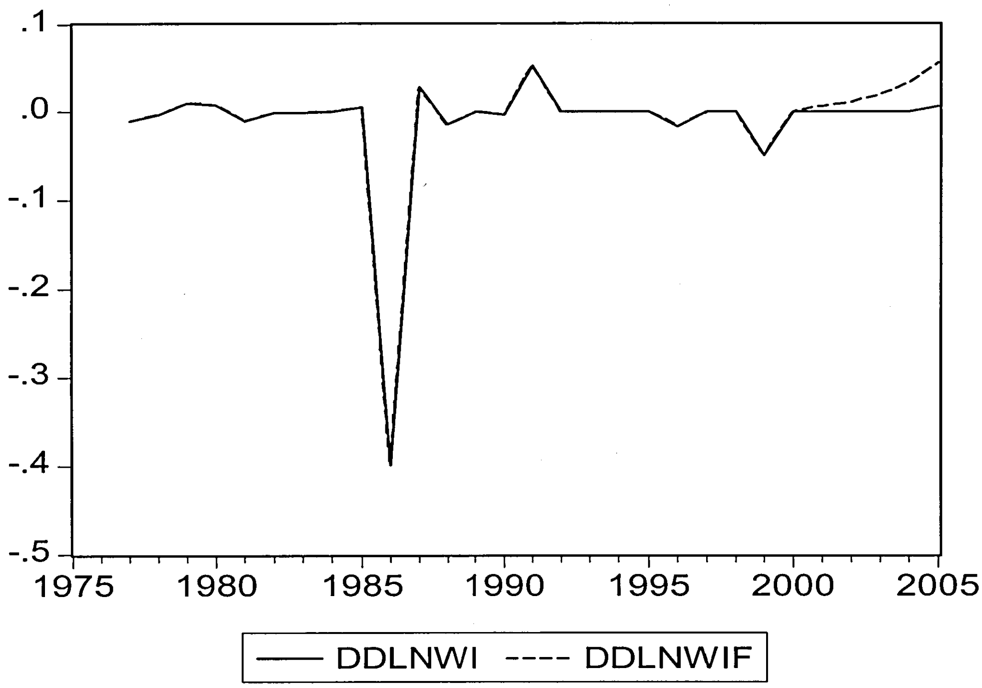
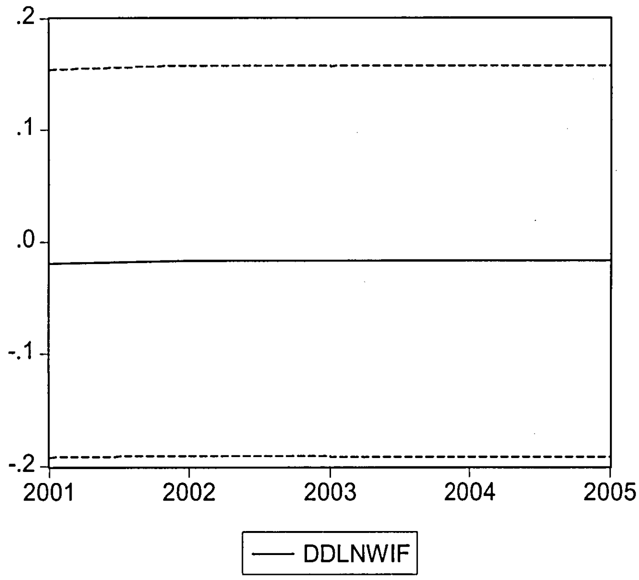


Table (A7.44)
Estimate ARMA (1,1,0) 1975-2000

Dependent Variable: DDLNWI				
Method: Least Squares				
Date: 05/15/07 Time: 12:35				
Sample(adjusted): 1978 2000				
Included observations: 23 after adjusting endpoints				
Convergence achieved after 3 iterations				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.017138	0.015942	-1.075029	0.2946
AR(1)	-0.131197	0.216510	-0.605961	0.5510
R-squared	0.017185	Mean dependent var		-0.017082
Adjusted R-squared	-0.029616	S.D. dependent var		0.085230
S.E. of regression	0.086483	Akaike info criterion		-1.974789
Sum squared resid	0.157067	Schwarz criterion		-1.876050
Log likelihood	24.71007	F-statistic		0.367189
Durbin-Watson stat	2.004644	Prob(F-statistic)		0.551035
Inverted AR Roots	-.13			

Dynamic Forecast

Figure (A7.34)

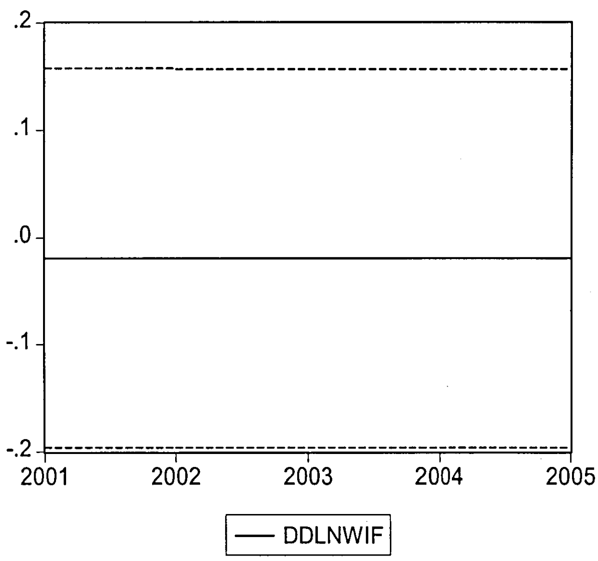


Forecast: DDLNWIF
Actual: DDLNWI
Forecast sample: 2001 2005
Included observations: 5

Root Mean Squared Error	0.019110
Mean Absolute Error	0.018911
Mean Abs. Percent Error	29012.06
Theil Inequality Coefficient	0.924281
Bias Proportion	0.979276
Variance Proportion	0.009513
Covariance Proportion	0.011211

Static Forecast

Figure (A7.35)



Forecast: DDLNWIF
Actual: DDLNWI
Forecast sample: 2001 2005
Included observations: 5

Root Mean Squared Error	0.020946
Mean Absolute Error	0.020759
Mean Abs. Percent Error	31478.38
Theil Inequality Coefficient	0.930979
Bias Proportion	0.982232
Variance Proportion	0.017734
Covariance Proportion	0.000034

Results of Forecasting from 2006-2020

Table (A7. 45)

Dependent Variable: D(LNW)				
Method: Least Squares				
Date: 06/18/07 Time: 10:39				
Sample(adjusted): 1979 2005				
Included observations: 27 after adjusting endpoints				
Convergence achieved after 299 iterations				
Backcast: OFF (Roots of MA process too large)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.112299	0.039283	2.858709	0.0091
AR(1)	1.123062	0.178656	6.286183	0.0000
AR(2)	0.548507	0.242619	2.260778	0.0340
AR(3)	-0.826215	0.172901	-4.778554	0.0001
MA(1)	-1.594021	0.377511	-4.222450	0.0004
R-squared	0.694480	Mean dependent var		0.087853
Adjusted R-squared	0.638931	S.D. dependent var		0.116484
S.E. of regression	0.069994	Akaike info criterion		-2.315238
Sum squared resid	0.107782	Schwarz criterion		-2.075268
Log likelihood	36.25571	F-statistic		12.50212
Durbin-Watson stat	2.471074	Prob(F-statistic)		0.000019
Inverted AR Roots	.97 -.29i	.97+.29i	-.81	
	Estimated AR process is nonstationary			
Inverted MA Roots	1.59			
	Estimated MA process is noninvertible			

Figure (A7. 36)

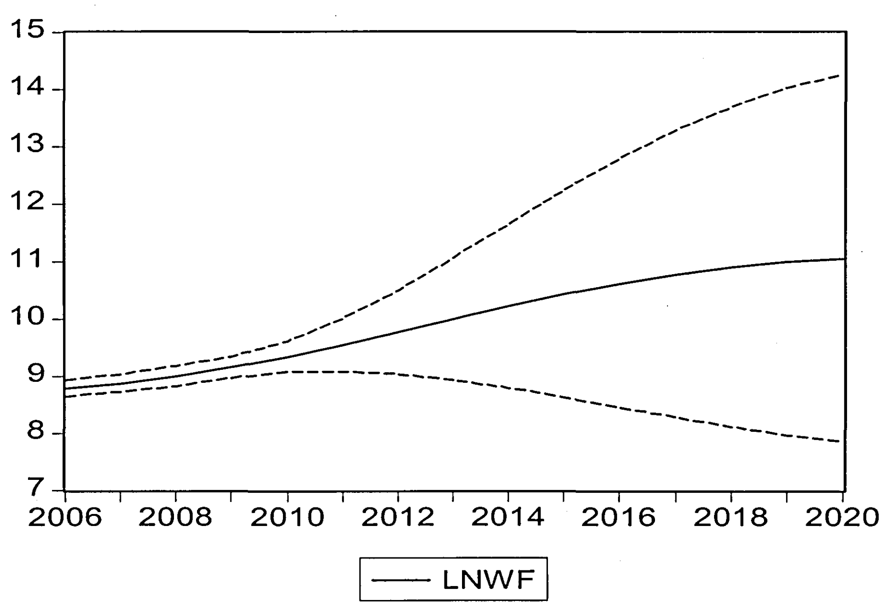


Table (A7.46)

Year	LNWF	WF
2006	8.779444	6293.89
2007	8.868135	6545.55
2008	8.995219	6834.94
2009	9.148183	7158.08
2010	9.333766	7546.32
2011	9.538457	7632.16
2012	9.761116	8320.49
2013	9.987486	8762.91
2014	10.21209	9228.97
2015	10.42190	9730.54
2016	10.61107	10226.21
2017	10.77039	10755.52
2018	10.89710	11305.71
2019	10.98787	11877.78
2020	11.04503	12473.20

Table (A7.47)

Dependent Variable: D(LNWA)				
Method: Least Squares				
Date: 06/12/07 Time: 17:01				
Sample(adjusted): 1979 2005				
Included observations: 27 after adjusting endpoints				
Failure to improve SSR after 26 iterations				
Backcast: 1978				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.049685	0.014615	3.399593	0.0026
AR(1)	0.887734	0.188446	4.710812	0.0001
AR(2)	0.392450	0.254224	1.543718	0.1369
AR(3)	-0.446735	0.172529	-2.589327	0.0167
MA(1)	-0.997354	0.102814	-9.700589	0.0000
R-squared	0.511382	Mean dependent var		0.094685
Adjusted R-squared	0.422542	S.D. dependent var		0.135671
S.E. of regression	0.103097	Akaike info criterion		-1.540715
Sum squared resid	0.233838	Schwarz criterion		-1.300745
Log likelihood	25.79966	F-statistic		5.756226
Durbin-Watson stat	2.069337	Prob(F-statistic)		0.002511
Inverted AR Roots	.78 -.23i	.78+.23i	-.67	
Inverted MA Roots	1.00			

Figure (A7.37)

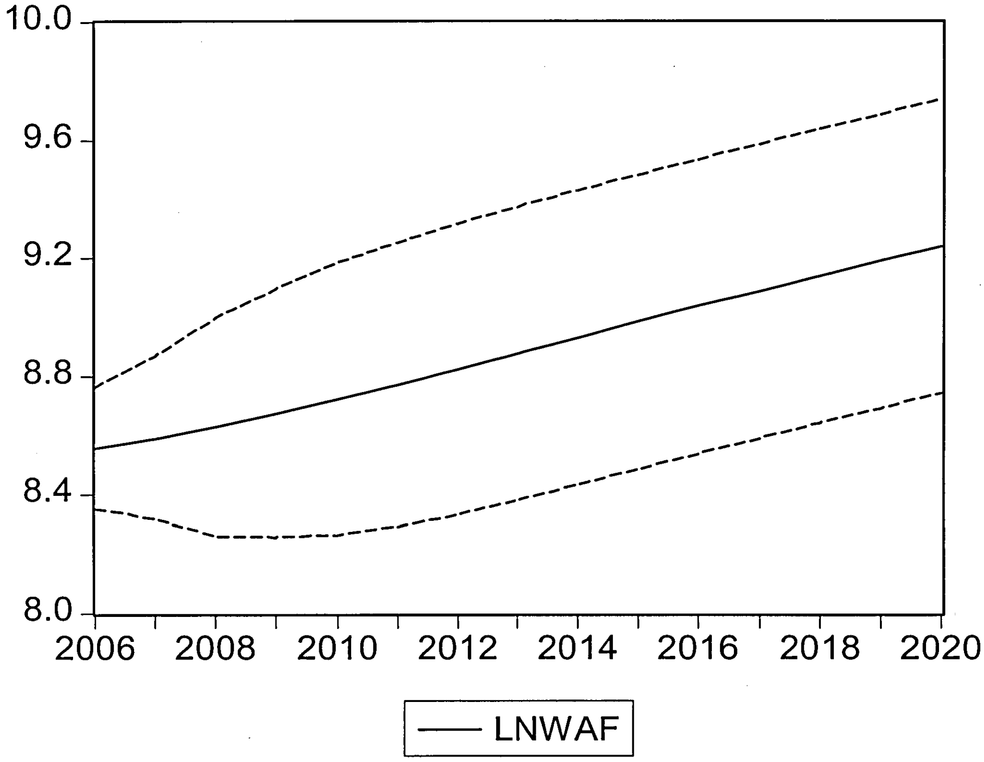


Table (A7.48)

Year	LNWAF	WAF
2006	8.557265	5204.43
2007	8.591240	5384.29
2008	8.630798	5601.55
2009	8.674951	5854.41
2010	8.722768	6171.39
2011	8.773148	6194.89
2012	8.825189	6803.48
2013	8.878072	7172.95
2014	8.931210	7564.41
2015	8.984163	7975.77
2016	9.036675	8405.78
2017	9.088610	8853.87
2018	9.139942	9320.22
2019	9.190710	9805.61
2020	9.240996	10311.30

Table (A7.59)

Dependent Variable: D(LNWD)				
Method: Least Squares				
Date: 06/12/07 Time: 17:13				
Sample(adjusted): 1977 2002				
Included observations: 26 after adjusting endpoints				
Convergence achieved after 18 iterations				
Backcast: 1976				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.046733	0.008267	5.652766	0.0000
AR(1)	0.752444	0.088334	8.518183	0.0000
MA(1)	-0.997424	0.096770	-10.30712	0.0000
R-squared	0.194704	Mean dependent var		0.058975
Adjusted R-squared	0.124678	S.D. dependent var		0.083955
S.E. of regression	0.078547	Akaike info criterion		-2.142061
Sum squared resid	0.141903	Schwarz criterion		-1.996896
Log likelihood	30.84679	F-statistic		2.780464
Durbin-Watson stat	1.877546	Prob(F-statistic)		0.082887
Inverted AR Roots	.75			
Inverted MA Roots	1.00			

Figure (A7.38)

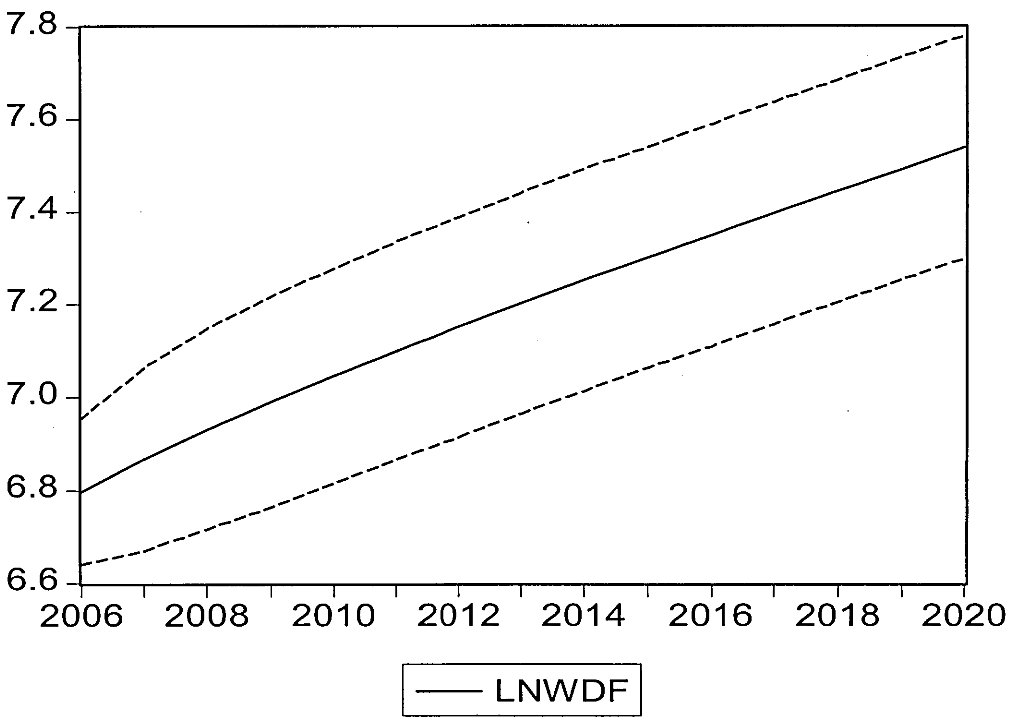


Table (A7.50)

Year	DLNWdF	WdF
2006	6.797657	895.75
2007	6.866585	958.96
2008	6.930019	1022.69
2009	6.989319	1084.98
2010	7.045508	1147.69
2011	7.099356	1204.19
2012	7.151443	1275.93
2013	7.202204	1342.17
2014	7.251969	1410.49
2015	7.300983	1494.92
2016	7.349432	1555.31
2017	7.397457	1631.83
2018	7.445162	1711.56
2019	7.492627	1794.76
2020	7.539910	1881.66

Table (A7.51)

Dependent Variable: D(LNWI,2)				
Method: Least Squares				
Date: 06/18/07 Time: 11:51				
Sample(adjusted): 1978 2005				
Included observations: 28 after adjusting endpoints				
Convergence achieved after 121 iterations				
Backcast: OFF (Roots of MA process too large)				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.002471	0.008517	-0.290107	0.7741
AR(1)	0.553156	0.169294	3.267437	0.0031
MA(1)	-1.453939	0.219515	-6.623402	0.0000
R-squared	0.517827	Mean dependent var		-0.013786
Adjusted R-squared	0.479253	S.D. dependent var		0.077281
S.E. of regression	0.055768	Akaike info criterion		-2.834284
Sum squared resid	0.077751	Schwarz criterion		-2.691548
Log likelihood	42.67998	F-statistic		13.42430
Durbin-Watson stat	1.917242	Prob(F-statistic)		0.000110
Inverted AR Roots	.55			
Inverted MA Roots	1.45			
	Estimated MA process is noninvertible			

Table (A7. 52)

Year	LNWIF	WIF
2006	5.266637	193.71
2007	5.309765	202.30
2008	5.350045	210.70
2009	5.387645	218.69
2010	5.422660	227.24
2011	5.455139	233.08
2012	5.485112	241.08
2013	5.512595	247.79
2014	5.537597	254.07
2015	5.560121	259.85
2016	5.580172	265.12
2017	5.597750	269.82
2018	5.612856	273.93
2019	5.625491	277.41
2020	5.635655	280.24

Engle-Granger Two-Step Procedure

First Stage

Table (A8.1)

Dependent Variable: LNWA				
Method: Least Squares				
Date: 06/20/07 Time: 15:38				
Sample: 1975 2005				
Included observations: 31				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-33.92030	8.206916	-3.133136	0.0003
LNRY	0.184106	0.188903	0.974607	0.3387
LNPOP	2.831555	0.272011	8.40970	0.0000
LNRPA	-0.266061	0.112910	-3.356405	0.0263
LNTEMP	0.070355	2.864009	0.024565	0.9806
R-squared	0.918183	Mean dependent var		7.594235
Adjusted R-squared	0.905595	S.D. dependent var		0.937743
S.E. of regression	0.288125	Akaike info criterion		0.495843
Sum squared resid	2.158411	Schwarz criterion		0.727131
Log likelihood	-2.685567	F-statistic		72.94521
Durbin-Watson stat	1.313855	Prob(F-statistic)		0.000000

Table (A8.2)

Unit root test for residuals for lnwa with four lags

ADF Test Statistic	-2.430800	1% Critical Value*		-2.6560
		5% Critical Value		-1.9546
		10% Critical Value		-1.6226
*MacKinnon critical values for rejection of hypothesis of a unit root.				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(RESIDLNWA)				
Method: Least Squares				
Date: 06/20/07 Time: 15:43				
Sample(adjusted): 1980 2005				
Included observations: 26 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESIDLNWA(-1)	-0.412737	0.169795	-2.430800	0.0241
D(RESIDLNWA(-1))	0.152476	0.203061	0.750886	0.4611
D(RESIDLNWA(-2))	0.327730	0.199524	1.642562	0.1154
D(RESIDLNWA(-3))	0.265461	0.210679	1.260026	0.2215
D(RESIDLNWA(-4))	0.110495	0.213339	0.517929	0.6099
R-squared	0.254454	Mean dependent var		-0.001595
Adjusted R-squared	0.112445	S.D. dependent var		0.163595
S.E. of regression	0.154123	Akaike info criterion		-0.731093
Sum squared resid	0.498831	Schwarz criterion		-0.489151
Log likelihood	14.50420	Durbin-Watson stat		1.730312

Table (A8.3)

Dependent Variable: LNWD				
Method: Least Squares				
Date: 06/20/07 Time: 15:46				
Sample: 1975 2005				
Included observations: 31				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-22.77153	3.156962	-8.213115	0.0000
LNRY	0.149467	0.065865	3.269282	0.0318
LNPOP	1.698313	0.089994	16.87147	0.0000
LNRPD	-0.141313	0.044266	3.192382	0.0037
LNTEMP	1.272417	1.091775	1.165457	0.2544
R-squared	0.962083	Mean dependent var		5.926232
Adjusted R-squared	0.956250	S.D. dependent var		0.529098
S.E. of regression	0.110669	Akaike info criterion		-1.417860
Sum squared resid	0.318437	Schwarz criterion		-1.186571
Log likelihood	26.97683	F-statistic		164.9284
Durbin-Watson stat	1.829758	Prob(F-statistic)		0.000000

Table (A8. 4)

Unit Root test for Residuals for lnwd with One Lag

ADF Test Statistic	-2.884370	1% Critical Value*		-2.6453
		5% Critical Value		-1.9530
		10% Critical Value		-1.6218
*MacKinnon critical values for rejection of hypothesis of a unit root.				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(RESIDLNWD)				
Method: Least Squares				
Date: 06/20/07 Time: 15:48				
Sample(adjusted): 1977 2005				
Included observations: 29 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESIDLNWD(-1)	-0.402363	0.139498	-2.884370	0.0076
D(RESIDLNWD(-1))	0.097033	0.151961	0.638540	0.5285
R-squared	0.239068	Mean dependent var		0.008031
Adjusted R-squared	0.210885	S.D. dependent var		0.078502
S.E. of regression	0.069735	Akaike info criterion		-2.421768
Sum squared resid	0.131299	Schwarz criterion		-2.327472
Log likelihood	37.11564	Durbin-Watson stat		2.079146

Table (A8.5)

Dependent Variable: LNWI				
Method: Least Squares				
Date: 06/20/07 Time: 15:50				
Sample: 1975 2005				
Included observations: 31				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-78.45457	17.17974	-5.566692	0.0001
LNRY	0.343927	0.395435	0.869744	0.3924
LNPOP	4.995168	0.569408	7.772569	0.0000
LNRPI	-0.490225	0.236357	-3.074090	0.0481
LNTEMP	2.757144	5.995299	0.459884	0.6494
R-squared	0.893930	Mean dependent var		3.538364
Adjusted R-squared	0.877611	S.D. dependent var		1.724035
S.E. of regression	0.603138	Akaike info criterion		1.973350
Sum squared resid	9.458172	Schwarz criterion		2.204638
Log likelihood	-25.58692	F-statistic		54.78012
Durbin-Watson stat	1.138959	Prob(F-statistic)		0.000000

Table (A8.6)

Unit Root test for Residuals for lnwi with Zero Lag

ADF Test Statistic	-2.253980	1% Critical Value*		-2.6423
		5% Critical Value		-1.9526
		10% Critical Value		-1.6216
*MacKinnon critical values for rejection of hypothesis of a unit root.				
Augmented Dickey-Fuller Test Equation				
Dependent Variable: D(RESIDLNWI)				
Method: Least Squares				
Date: 06/20/07 Time: 15:52				
Sample(adjusted): 1976 2005				
Included observations: 30 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
RESIDLNWI(-1)	-0.147560	0.065466	-2.253980	0.0319
R-squared	0.139454	Mean dependent var		0.022128
Adjusted R-squared	0.139454	S.D. dependent var		0.211693
S.E. of regression	0.196378	Akaike info criterion		-0.384781
Sum squared resid	1.118370	Schwarz criterion		-0.338075
Log likelihood	6.771717	Durbin-Watson stat		1.343445

Second Stage
Estimation of the Error Correction Model (ECM)

Table (A8.7)

Dependent Variable: D(LNWA)				
Method: Least Squares				
Date: 06/21/07 Time: 13:28				
Sample(adjusted): 1979 2005				
Included observations: 27 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.113000	0.096520	4.130737	0.0008
D(LNRPA)	-0.031718	0.075331	-2.361045	0.0250
D(LNPOP)	0.209485	2.793832	10.414981	0.0000
D(LNRY)	0.013142	0.087207	0.970698	0.0881
D(LNTEMP)	0.042424	1.049497	0.414233	0.6901
RESIDLNWA(-4)	-0.264905	0.108931	2.431859	0.0241
R-squared	0.927414	Mean dependent var		0.094685
Adjusted R-squared	0.77989	S.D. dependent var		0.135671
S.E. of regression	0.129209	Akaike info criterion		-1.061643
Sum squared resid	0.350594	Schwarz criterion		-0.773679
Log likelihood	20.33218	F-statistic		1.533117
Durbin-Watson stat	2.135554	Prob(F-statistic)		0.222338

Table (A8. 8)

Dependent Variable: D(LNWD)				
Method: Least Squares				
Date: 06/21/07 Time: 13:40				
Sample(adjusted): 1976 2005				
Included observations: 30 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.072770	0.048365	7.214583	0.0000
D(LNRPD)	-0.042285	0.028023	-3.198926	0.0004
D(LNPOP)	0.392790	1.393001	18.78174	0.0000
D(LNRY)	0.056772	0.042149	2.276938	0.0027
D(LNTEMP)	0.827653	0.480562	1.722260	0.0179
RESIDLNWD(-1)	-0.385110	0.136556	-2.820155	0.0095
R-squared	0.962953	Mean dependent var		0.063696
Adjusted R-squared	0.866068	S.D. dependent var		0.079017
S.E. of regression	0.070407	Akaike info criterion		-2.292198
Sum squared resid	0.118971	Schwarz criterion		-2.011958
Log likelihood	40.38297	F-statistic		2.505413
Durbin-Watson stat	1.713797	Prob(F-statistic)		0.058250

Table (A8.9)
Second Difference

Dependent Variable: D(LNWI,2)				
Method: Least Squares				
Date: 06/21/07 Time: 13:43				
Sample(adjusted): 1977 2005				
Included observations: 29 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.026515	0.055161	-4.580689	0.0003
D(LNRPI)	-0.018738	0.045329	-2.073382	0.0072
D(LNPOP)	0.430771	1.568235	8.777465	0.0000
D(LNRY)	0.048179	0.053505	0.900473	0.3772
D(LNTEMP)	0.209797	0.583756	0.359392	0.7226
RESIDLNWI	-0.023571	0.035212	-0.669418	0.5099
R-squared	0.897150	Mean dependent var		-0.013691
Adjusted R-squared	-0.853470	S.D. dependent var		0.075890
S.E. of regression	0.080438	Akaike info criterion		-2.020658
Sum squared resid	0.148818	Schwarz criterion		-1.737770
Log likelihood	35.29955	F-statistic		0.384558
Durbin-Watson stat	2.352569	Prob(F-statistic)		0.854187

Table (A8.10)

Dependent Variable: D(LNWI,2)				
Method: Least Squares				
Date: 06/21/07 Time: 14:11				
Sample(adjusted): 1977 2005				
Included observations: 29 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.020333	0.060516	-0.335986	0.7399
D(LNRPI)	0.024791	0.049629	0.499524	0.6222
D(LNPOP)	0.207516	1.738439	0.119369	0.9060
D(LNRY)	-0.052104	0.054222	-0.960938	0.3466
D(LNTEMP)	-0.175494	0.585220	-0.299877	0.7670
RESIDLNWI(-2)	-0.020481	0.035297	-0.580230	0.5674
R-squared	0.072742	Mean dependent var		-0.013691
Adjusted R-squared	-0.128835	S.D. dependent var		0.075890
S.E. of regression	0.080630	Akaike info criterion		-2.015894
Sum squared resid	0.149529	Schwarz criterion		-1.733005
Log likelihood	35.23046	F-statistic		0.360866
Durbin-Watson stat	2.385329	Prob(F-statistic)		0.869895

Table (A8.11)

With First Difference

Dependent Variable: D(LNWI)				
Method: Least Squares				
Date: 08/28/07 Time: 11:08				
Sample(adjusted): 1976 2005				
Included observations: 30 after adjusting endpoints				
Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-0.063151	0.110958	-0.569145	0.5743
D(LNRY)	-0.054821	0.112938	-0.485410	0.6316
D(LNRPI)	0.090955	0.093716	0.970534	0.3411
D(LNPOP)	7.628354	3.166539	2.409051	0.0237
D(LNTEMP)	0.885239	1.221046	0.724984	0.4752
R-squared	0.211088	Mean dependent var		0.193940
Adjusted R-squared	0.084862	S.D. dependent var		0.178734
S.E. of regression	0.170982	Akaike info criterion		-0.543504
Sum squared resid	0.730872	Schwarz criterion		-0.309972
Log likelihood	13.15257	F-statistic		1.672305
Durbin-Watson stat	0.750565	Prob(F-statistic)		0.187841

Appendix B

World Business Institute

ABN: 62 087 222 400

31 Blake Street, Berwick 3806, Victoria, Australia
Phone : (61 3) 9702 2734 and Fax : (61 3) 9702 0122
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Dr. Mohammad Hoque

IBR Conference Coordinator